**A REPORT OF THE AAWG**
**RECOMMENDATIONS FOR REGULATORY ACTION TO PREVENT WIDESPREAD FATIGUE DAMAGE IN THE COMMERCIAL AIRPLANE FLEET**

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# LIST OF ABBREVIATIONS

The following abbreviations are used throughout this report

| | |
|---|---|
| AATF | Airworthiness Assurance Task Force |
| AAWG | Airworthiness Assurance Working Group |
| AC | Advisory Circular (FAR) |
| ACJ | Advisory Circular (JAR) |
| AD | Airworthiness Directive |
| AECMA | Association des Entreprises de Construction M canique et Aeronautique |
| AIA | Aerospace Industries Association of America |
| ALI | Airworthiness Limitation Instructions |
| ARAC | Aviation Rulemaking Advisory Committee |
| ART | Authorities Review Team |
| ATA | Air Transport Association of America |
| CAA-UK | Civil Aviation Authority - United Kingdom |
| CTOA | Crack Tip Opening Angle |
| DGAC | Direction G n rale de l Aviation Civile |
| DSG | Design Service Goal |
| EIFS | Equivalent Initial Flaw Size |
| ESG | Extended Service Goal |
| FAA | Federal Aviation Administration |
| FAR | Federal Aviation Regulation |
| GARTEUR | Group for Aeronautical Research and Technology in Europe |
| HMV | Heavy Maintenance Visit |
| IATA | International Air Transport Association |
| ICWFD | Industry Committee on Widespread Fatigue Damage |
| JAA | Joint Aviation Authorities |
| JAR | Joint Aviation Requirement |
| MED | Multiple Element Damage |
| MSD | Multiple Site Damage |
| NAARP | National Aging Aircraft Research Program |
| NDI | Non Destructive Inspection |
| NP | None Planned at this time |
| NPRM | Notice of Proposed Rulemaking |
| NTSB | National Transportation Safety Board |
| OEM | Original Equipment Manufacturer |
| PMI | Principal Maintenance Inspector (FAA) |
| POD | Probability of Detection |
| RS | Residual Strength |
| SAETG | Structural Audit Evaluation Task Group |
| SB | Service Bulletin |
| SDR | Service Difficulty Report (FAA) |
| SFAR | Special Federal Aviation Regulation |
| SIA | Structural Integrity Audit |
| SIF | Stress Intensity Factors |
| SMAAC | Structural Maintenance of Aging Aircraft |
| SSIP | Supplemental Structural Inspection Program |
| STC | Supplemental Type Certificate |
| STG | Structures Task Group |
| TAEIG | Transport Airplane and Engines Issues Group |
| TARC | Technical Advisory Regulatory Committee |
| TC | Type Certification |
| TOGAA | Technical Oversight Group RE: Aging Aircraft |
| WFD | Widespread Fatigue Damage |

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[4] Anon., *Continuing structural integrity program for large transport category airplanes*, FAA Advisory Circular No. 91-56A, Federal Aviation Administration, U.S. Department of Transport (April 1998)

[5] Anon., Equipment, systems and installations , Federal Aviation Regulations Part 25 - Airworthiness Standards: Transport Category Airplanes, Change 10, Section 25.1309, Federal Aviation Administration, Department of Transportation, Washington D.C. (March 1997)

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[7] Anon., Engines , Federal Aviation Regulations Part 25 - Airworthiness Standards: Transport Category Airplanes, Change 12, Section 25.903, Federal Aviation Administration, Department of Transportation, Washington D.C. (March1998)

[8] Anon., Turbine engine installations , Joint Aviation Requirements JAR-25 - Large Aeroplanes, Change 14, Paragraph JAR 25.903, Section (d), Joint Aviation Authorities, Hoofddorp, The Netherlands (May 1994)

[9] Anon., Damage-tolerance and fatigue evaluation of structure , Federal Aviation Regulations Part 25 - Airworthiness Standards: Transport Category Airplanes, Change 11, Section 25.571, Federal Aviation Administration, Department of Transportation, Washington D.C. (August 1997)

[10] Anon., Damage-tolerance and fatigue evaluation of structure , Joint Aviation Requirements JAR-25 - Large Aeroplanes, Change 14, Paragraph JAR 25.571, Section (e), Joint Aviation Authorities, Hoofddorp, The Netherlands (May 1994)

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## A REPORT OF THE AAWG
## RECOMMENDATIONS FOR REGULATORY ACTION TO PREVENT WIDESPREAD FATIGUE DAMAGE IN THE COMMERCIAL AIRPLANE FLEET

# REVISION PAGE

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| - | 3-11-99 | Initial Release | - | - | - | - |
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# 1.0 EXECUTIVE SUMMARY

In August 1997, the FAA and JAA issued a Tasking Statement through the Aviation Rulemaking Advisory Committee (ARAC). This Tasking Statement requesting that a non-advocate group be formed to examine whether or not rule-making should be initiated that would require audits of airplane structure to preclude the occurrence of widespread fatigue damage in the commercial airplane fleet. This report represents the work product of that Tasking Statement.

The Tasking was assigned to the Airworthiness Assurance Working Group (AAWG) in September 1997. This report is the culmination of 18 months of effort. In the process of the work, several conclusions and recommendations were reached. These results are presented below.

## *1.1 CONCLUSIONS*

- With respect to the 1993 AAWG Report entitled Structural Fatigue Evaluation for Aging Airplanes
  - That the conclusions and recommendations of the 1993 AAWG Report are still generally applicable.
  - That AC 91-56A, released in April 1998 by the FAA has many inconsistencies in use of terminology and should be corrected.
  - That the list of structure susceptible to MSD/MED from the 1993 AAWG Report has been validated and expanded to include additional examples from industry experience.
  - That interaction of discrete source damage and MSD/MED need not be considered as assessment of total risk is within acceptable limits.
  - That because of the instances of MSD/MED in the fleet and the continued reliance on surveillance types of inspections to discover such damage, rules and advisory material should be developed that would provide specific programs to preclude WFD in the fleet.
- With respect to maintenance programs:
  - That an effective aging airplane program including a Mandatory Modification Program, Corrosion Prevention and Control Program, Repair Assessment Program, and a structural supplemental inspection program (SSID or ALI) is a necessary prerequisite for an effective program for MSD/MED.
  - That as long as there is an effective corrosion prevention and control program, interaction of MSD/MED with environmental degradation is minimized.

- That the use of a Monitoring Period for the management of potential multiple site damage and multiple element damage (MSD/MED) scenarios in the fleet is possible if MSD/MED cracking is detectable before the structure loses its required residual strength.
- That any program established to correct MSD or MED in the fleet needs careful consideration for the necessary lead times to develop resources to implement fleet action.

- That there is no universally acceptable or required damage size used for certification compliance.

- With respect to research programs:

  - That additional research into the residual strength behavior of structure with MSD/MED should be conducted to supplement existing database.
  - That the highest potential to achieve the necessary improvements of flaw detectability is seen in the field of semi-automated eddy current systems.

- With respect to the Fleet Health and MSD:

  - That every pre-amendment 45 commercial jet type airplane has had instances of MSD/MED in either test or service.
  - That normal inspections (e.g. maintenance programs plus aging airplane programs) conducted by the airlines using procedures developed by the manufacturer have found numerous instances of MSD/MED in the fleet since 1988.
  - That the value of SDRs in determining the health of the fleet with respect to MSD/MED occurrence is limited.

- With respect to Analytical Assessment of MSD/MED:

  - Sufficient technology exists to complete the audit in a conservative manner.
  - That most OEMs have voluntary WFD audit programs in progress.
  - That damage scenarios involving combinations of MSD and MED must be considered if there is a possibility of interaction.
  - That the AAWG participating manufacturers have developed different but viable means of calculating the necessary parameters to characterize MSD/MED and define appropriate maintenance actions whether it be a monitoring period or structure modification/replacement.
  - That the analysis procedures used to characterize MSD/MED scenarios on airplanes needs careful correlation with test and service evidence.

## 1.2 RECOMMENDATIONS

The following recommendations are made as a result of this study:

- That the FAA review and make changes to AC 91-56A as delineated in section 4.2.1 and 4.2.2 of this report. These changes are intended to remove ambiguous use of terminology and provide additional guidance for entities performing the structural Audit
- That the FAA fund research detailed in Section 6.0, In addition:
  - Every effort should be made to make data from tests conducted in all research programs available at the earliest possible time before formal reports are issued.
  - Tests currently funded, involving lead crack link-up, should be accomplished as soon as possible to support the first round of audits due in three years.
- That the FAA issue a subsequent tasking to ARAC to develop necessary new and/or revised certification and operational rules with advisory material to make mandatory audit requirements for MSD/MED for all transport category airplanes. This recommendation includes the development of rules and advisory material as detailed in Section 10.0.
  - Existing Transport Category Airplanes - A FAA 121 (New) Rule and/or Part 39 (Amended)
  - New Certification Programs
    - FAA 25.1529 rule revision
    - FAA 121 (New) Rule for Operator Compliance
  - FAA AC for Both 121 (New) and 25.1529 (Revised) Rule
- That WFD audits for nearly all pre-amendment 45 commercial jet airplanes should be completed and OEM documents published by December 31, 2001, with some exceptions. On other commercial jet transports, audits should be completed before the high time airplane reaches their respective design service goals.
- That a SSIP or equivalent program and Repair Assessment Program for Post Amendment 45/Pre Amendment 54 airplane be developed and implemented.
- That any rule published as a result of the subsequent tasking become effective one year after final rule publication.
- That the analysis of STCs to primary structure be held to the same audit requirements (criteria and schedule) as OEM Structure.

## 2.0 AVIATION RULEMAKING ADVISORY COMMITTEE TASKING

On August 28, 1997, the FAA formally notified the Aviation Rulemaking Advisory Committee; Transport Airplane and Engines Group through the Federal Register (Page 62 FR 45690 No. 167 08/28/97) of a new task assignment for action. The complete text of the Tasking Statement appears in Appendix A. Subsequently, the Transport Airplane and Engines Issues Group assigned action to the Airworthiness Assurance Working Group. The Task Assignment involves completion of the following tasks.

**Task Title:** ANM-97-434-A - Task 5: FAR/JAR 25, Aging Aircraft

**Task Description:**

(1) ARAC is tasked to review the capability of analytical methods and their validation; related research work; relevant full-scale and component fatigue test data; and tear down inspection reports, including fractographic analysis, relative to the detection of widespread fatigue damage (WFD). Since airplanes in the fleet provide important data for determining where and when WFD is occurring in the structure, ARAC will review fractographic data from representative fleet leader airplanes. Where sufficient relevant data for certain airplane models does not exist, ARAC will recommend how to obtain sufficient data from representative airplanes to determine the extent of WFD in the fleet. The review should take into account the Airworthiness Assurance Harmonization Working Group report Structural Fatigue Evaluation for Aging Aircraft dated October 14, 1993, and extend its applicability to all transport category airplanes having a maximum gross weight greater than 75,000 pounds.

(2) ARAC will produce time standards for the initiation and completion of model specific programs (relative to the airplane s design service goal) to predict, verify and rectify widespread fatigue damage. ARAC will also recommend action that the Authorities should take if a program, for certain model airplanes, is not initiated and completed prior to those time standards. Actions that ARAC will consider include regulations to require Type Certificate holders to develop WFD programs, modification action, operational limits, and inspection requirements to assure structural integrity of the airplanes. ARAC will provide a discussion of the relative merits of each option.

This task should be completed within 18 months of tasking.

As a result of the completion of the tasking, the FAA expects a task report detailing the investigations conducted along with recommendations for further FAA Action. While the recommendations may include a requirement to develop regulatory action, the actual writing of that requirement will be reserved to the FAA or assigned as an additional ARAC Tasking.

This report comprises the recommendations from the AAWG on the task assignment from ARAC. The Working Group Activity Reports presented to ARAC by the AAWG documenting the progress in completing the task are contained in Appendix B.

# 3.0 AIRWORTHINESS ASSURANCE WORKING GROUP

The AAWG is a duly constituted Federal Advisory Committee Act (FACA) entity. The AAWG reports to the Aviation Rulemaking Advisory Committee, Transport Airplane and Engine Issues Group (ARAC TAEIG). The AAWG was formed shortly after the 1988 Accident in Hawaii involving an older Boeing 737 in which a large section of fuselage departed the airplane. The AAWG has been active ever since examining the health of the fleet and proposing additional programs to maintain overall integrity of the commercial fleet. The membership of the AAWG consists of representation from:

Airbus Industrie*
Airline Pilot s Association
American Airlines
American West Airlines
Boeing Commercial Airplanes*
British Aerospace Airbus*
British Airways
Continental Airlines*
Delta Air Lines Incorporated*
DHL Airways Incorporated
Evergreen International Airlines
Federal Aviation Administration*
Federal Express*
Fokker Service
International Air Transport
Joint Airworthiness Authorities*
Lockheed Martin*
Northwest Airlines
Regional Airline Association
United Airlines
United Parcel Service
US Airways

The AAWG established a task group to prepare and finalize the recommendations from this Tasking. The entities identified by an asterisk, together with Daimler-Chrysler and Aerospatiale participated in the task group. In completing the Task, the AAWG met eleven times in the 18-month period. A list of meeting venues and meeting attendance is documented in Appendices C and D respectively.

# 4.0 BACKGROUND

In 1988, the industry experienced a significant failure of the airworthiness system. This system failure allowed an airplane to fly with significant unrepaired multiple site fatigue damage to the point where the airplane experienced a rapid fracture and loss of a portion of the fuselage. As a direct result of this accident, the FAA hosted The International Conference on Aging Airplanes on June 1-3, 1988 in Washington D. C. As a result of this conference, an organization of Operators, Manufacturers and Regulators was formed under the Federal Advisory Committee Act to investigate and propose solutions to the problems evidenced as a result of the accident. This group is now known as the Airworthiness Assurance Working Group (AAWG) (Formally know as the Airworthiness Assurance Task Force).

During the 1988 conference, several Airline/Manufacturer recommendations were presented to address the apparent short falls in the airworthiness system including Recommendation 3, which stated:

> "Continue to pursue the concept of teardown of the oldest airline aircraft to determine structural condition, and conduct fatigue tests of older airplanes per attached proposal."

In June 1989, the National Transportation Safety Board (NTSB) made Recommendation 89067 (Reference[1]) that requested the FAA to pursue necessary tasks to ensure continued safe operations with probable widespread fatigue damage (WFD). WFD was noted by the NTSB to be a contributing cause of the April 1988 Aloha Airlines 737 accident. The NTSB specifically recommended extended fatigue testing for older airplanes. In November 1989, the FAA responded by issuing a straw man SFAR RE: TWO-LIFE TIME FATIGUE TEST FOR OLDER AIRPLANES.

In June 1990, the AAWG tasked the formal evaluation of the AIA/ATA Recommendation 3. An alternative approach, Reference [2,3], to the straw man SFAR was developed by the AAWG and presented to the FAA in March 1991. The FAA accepted this alternative approach in June 1991. The AAWG was informally tasked to institutionalize the position in July.

The AAWG task objective was:

> The AAWG shall make recommendations on whether new or revised requirements for structural fatigue evaluation can and should be instituted as an airplane ages past its design service goal. These recommendations are limited to the A300 (Models B2, B4-100, B4-200, C4 and F4), BAC1-11, 707/720, 727, 737 (Models 100 and 200), 747 (Models 100 and 200), DC-8, DC-9, DC-10, F-28 and L-1011 airplanes.

In December 1992, the task was formally published in the Federal Register as an Aviation Rulemaking Advisory Committee (ARAC) task directed to the AAWG from the Transport Aircraft and Engine Issues Group (TAEIG). The task assigned was:

> Task 3 - Structural Fatigue Audit: Develop recommendations on whether new or revised requirements for structural fatigue evaluation and corrective action should be instituted and made mandatory as the airplane ages past its original design life goal.

In accomplishing the task, the AAWG assembled a subset of the working group to reach industry consensus. Industry participation in the task group included members from ATA, IATA, AIA, AECMA, FAA and JAA. In October of 1993, the AAWG formally presented their recommendations, Reference [3] to ARAC concerning Task 3. In general, those recommendations included a proposal for revising existing guidance material and that voluntary audits be conducted for the eleven AAWG models.

## 4.1 AFFIRMATION 1993 ARAC RECOMMENDATIONS

In 1993, ARAC made seven recommendations to the FAA and JAA concerning a structural audit for widespread fatigue damage. Those recommendations were:

### 4.1.1 1993 ARAC Recommendations

1. That the AAWG promote a WFD evaluation of each AAWG model within the existing STG environment, using the guidance of AC 91-56 as modified under Recommendation Number 2. These evaluations should be conducted in the timeliest possible fashion relative to the airplane model age.

2. That AC 91-56 be modified to include guidelines for WFD evaluation by the addition of Appendix 3 as shown in the 1993 AAWG Report, Reference [3].

3. That the STGs recommend appropriate fleet actions, through the SSIP or service bulletin modification programs.

4. That the AAWG be made responsible to monitor evaluation progress and results for consistency of approach for all models.

5. That mandatory action should enforce STG recommendations by normal FAA/JAA means.

6. That additional rule making is not necessary or desirable for timely achievement of the evaluation safety goals for the 11 AAWG Models.

7. That additional actions for airplanes currently in production should only be considered after completion of the initial evaluations of the 11 AAWG models.

The basic recommendation was to amend CAA Airworthiness Note 89 and FAA AC 91-56 to include guidance for a proposed structural audit for widespread fatigue damage (ARAC Recommendations 1 and 2). Furthermore, the report advocated that the audit would be performed voluntarily by the Structures Task Groups (STGs) under the direction of the manufacturers with any safety related issues being mandated by the regulators (ARAC Recommendation 3 and 5).

### 4.1.2 1999 Adjustments to the 1993 Recommendations

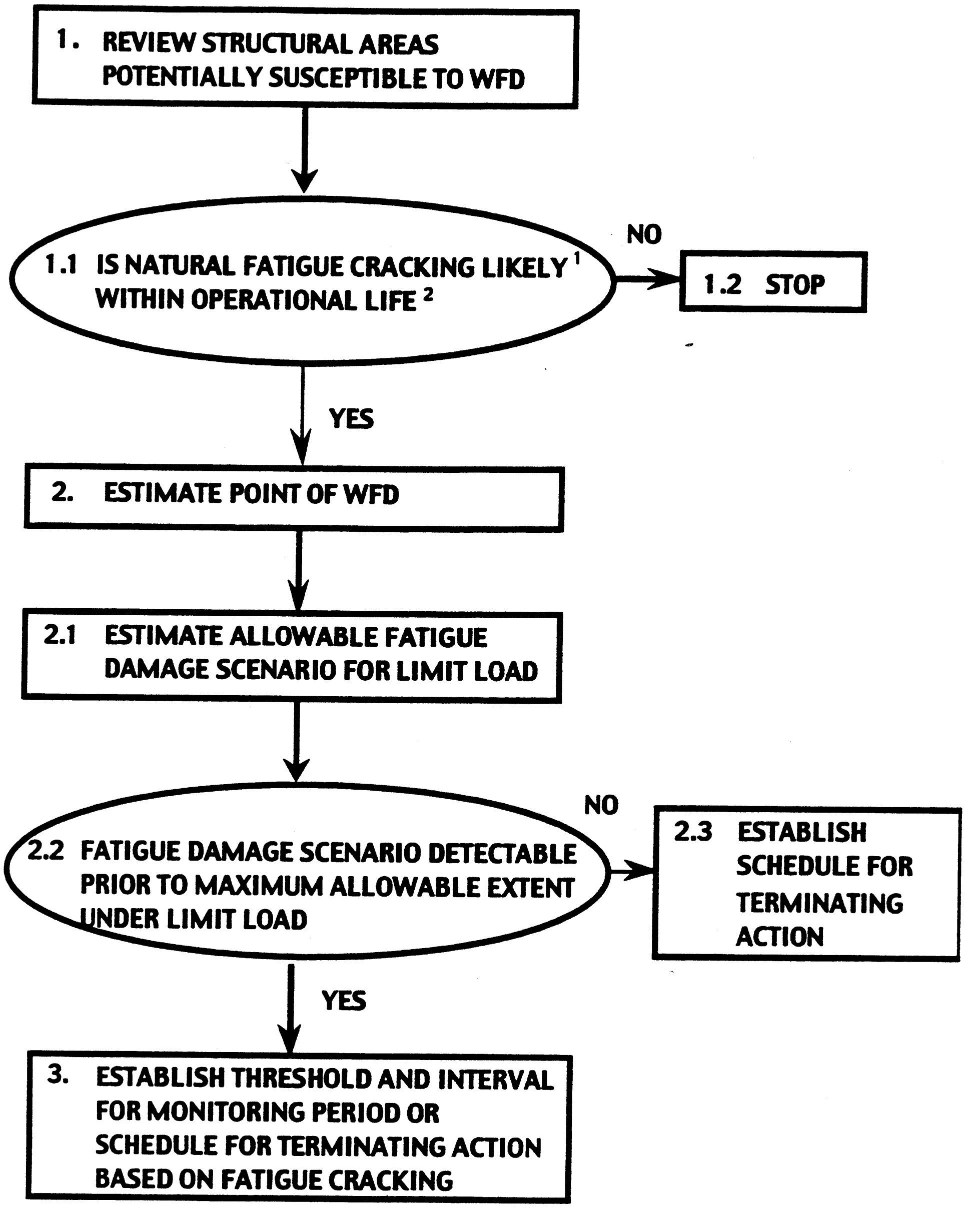
Six years have passed since these recommendations were made. A final copy of AC 91-56A was issued in April 1998 that goes well beyond the 1993 recommendations, being applicable to all large transport category airplanes (ARAC Recommendation 7). Beyond this one point, the 1993 recommendations are still generally valid as long as specific goals are being attained in the voluntary manufacturer audits. This report specifically looks at individual model requirements for the audits covering all large transport airplanes and the progress to complete those audits. Courses of action for the regulators to follow should a manufacturer not complete the audit are also examined (ARAC Recommendation 6).

The AAWG also looked on the recommendations made in the 1993 report in three specific areas. The first was with respect to the areas susceptible to MSD/MED. In reviewing these areas, the AAWG identified four additional design details that have a tendency to develop MSD/MED; these areas have been added to the complete compendium of details contained in Section 5.2 of this report.

Secondly, the AAWG examined Figure 1 of the 1993 Report, Reference [3], and proposed several changes to the Figure based on how an analysis would actually be performed. In addition the AAWG has now removed the requirement for the joint consideration of rotor burst and the presence of MSD/MED in the structure. The latter of these changes are discussed in detail in Section 5.3 of this report. The revised Figure 1 is shown in Figure 4.1.1.

Finally, the subject of monitoring period has been revisited with the purpose of defining with greater detail the circumstances and the limits with which this particular approach could be used. This is further discussed in Section 4.4 of this report.

## AIRPLANE EVALUATION PROCESS – STEP 1

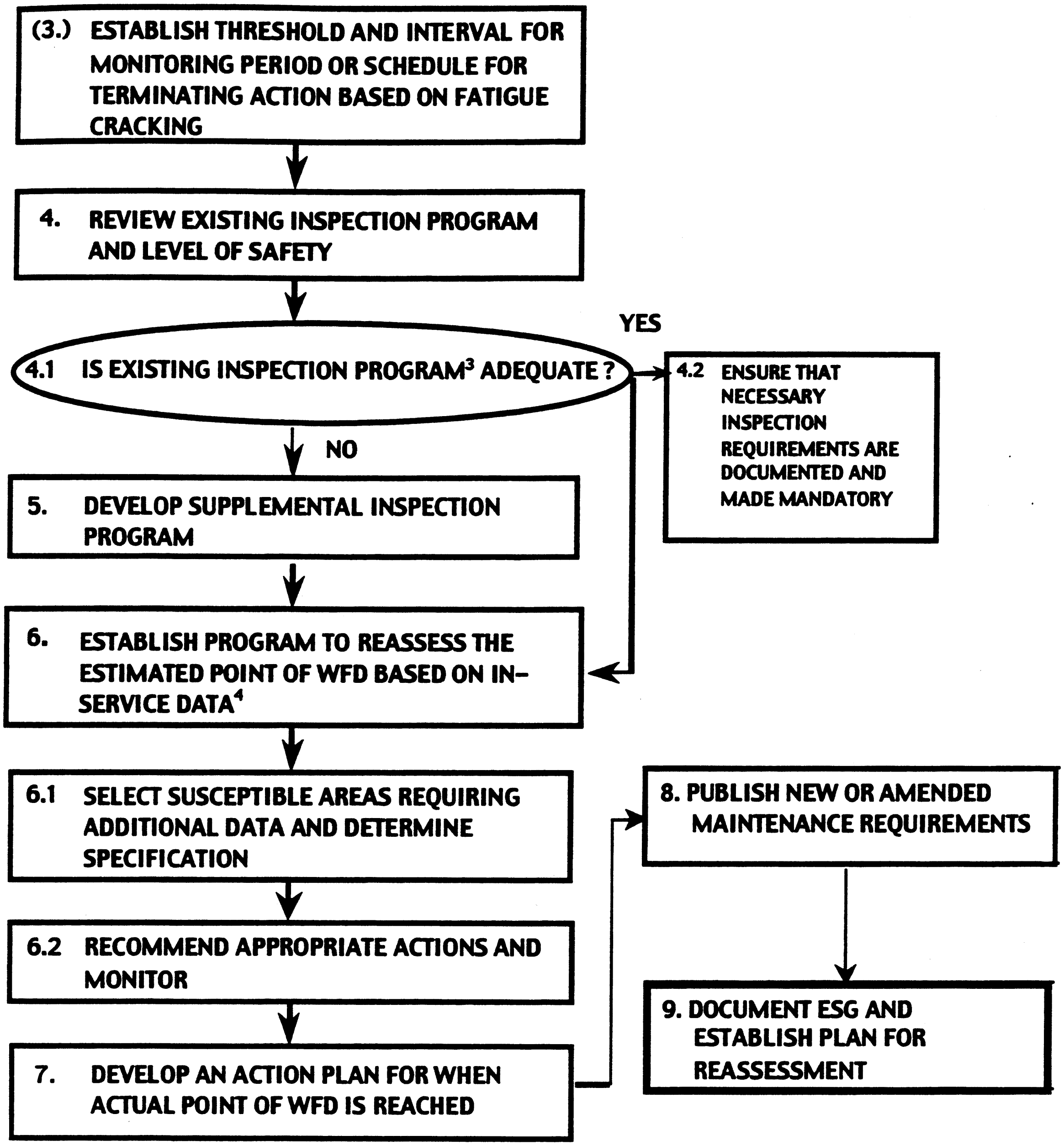



**NOTES:**

1. Fatigue cracking is defined as likely if the factored fatigue life is less than the projected ESG of the airplane at time of WFD evaluation.
2. The operational life is the projected ESG of the airplane at time of WFD evaluation.

**Figure 4.1.1 Airplane Evaluation Process**

## AIRPLANE EVALUATION PROCESS – STEP 2




**Notes:**

3. Inspection threshold, inspection intervals and inspection methods must be adequate to detect single or multiple cracking.
4. The evaluation process must be repeated if the operational life is increased

**Figure 4.1.1 Airplane Evaluation Process - Continued**

## 4.2 ADVISORY CIRCULAR 91-56A

In 1993, the second ARAC Recommendation to the FAA and JAA, Reference [3], proposed a modification to Advisory Circular 91-56, to include guidelines for a structural audit for Widespread Fatigue Damage. These guidelines were to be based on proposals contained within the 1993 Industry Committee report. A draft issue of the amended Advisory Circular, known as AC 91-56A, was issued in June 1997, and the AAWG subsequently undertook a review of the guidance material contained within this document. In addition, comments were solicited from ATA/AIA members.

In general, the AAWG concurred with the intent of AC 91-56A. The Advisory Circular implements many of the ARAC recommendations from 1993, although a number of general points may be noted, as follows:

- The scope of the Advisory Circular has been expanded to cover all large transport category airplanes, rather than the original 11 AAWG Models under consideration in 1993. However, this does not invalidate the 1993 Industry Committee proposals.

- The AAWG agrees with the need for OEMs to accomplish Widespread Fatigue Damage (WFD) assessment prior to operation of aging airplanes beyond DSG. However, it must be emphasised that the implementation of changes to the model-specific Supplemental Structural Inspection Program should be a joint effort by the Structures Task Group. Any service actions that require separate AD action should be processed through the ATA Airworthiness Concern Lead Airline Process.

- The AC is intended to be general in nature, and there are consequently many unknowns and hypothetical situations which would best be commented on when individual NPRMs are issued against each fleet to incorporate the WFD program.

Unfortunately, the draft AC was found to contain many inconsistencies, especially in dealing with terminology, and the AAWG made a number of specific recommendations to the FAA for revisions to the text. The majority of these suggestions were incorporated into the first issue of AC 91-56A, Reference [4], which was released in April 1998, although some concerns raised by the AAWG were not addressed by the modified document. This section summarizes the outstanding issues arising from the AAWG review, which have been allocated to one of the following three categories:

- Suggested text changes for clarification and understanding;
- Questions regarding the interpretation of wording or phrases in the text;
- Additional comments from operators.

### 4.2.1 Text Changes

The following changes to the text are suggested for clarification or to aid understanding. Paragraph numbers refer to the paragraph in AC 91-56A, Reference [4].

- Paragraph 6b: the second sentence states *Since the SID is applicable to all operators and is a safety concern for older airplanes...* . Since the purpose of the SID is to detect cracks before they result in a safety concern, this should be changed to read *Since the SID is applicable to all operators and is intended to address potential safety concerns on older airplanes...* .

- Paragraph 10: states that the development of a WFD program *should be initiated no later than the time when the high-time or high-cycle airplane in the fleet reaches three quarters of its Design Service Goal* . This should be changed to include and address airplanes that have already exceeded three quarters of their Design Service Goal as recommended in this report.

- Paragraph 11: the second and third sentences state *The same would be true for WFD AD's that require special inspections. WFD AD's that require structural modification would be handled separately.* Although the intention of the industry committee on WFD was that any areas of concerns arising from a WFD evaluation would be incorporated into existing programs such as the Aging Aircraft Modification Program or the SSID, the words here indicate that specific ADs for WFD will be issued if a concern is found. This should therefore be changed to read *The same would be true should the Aging Aircraft Modification Program or the SSID, mandated by AD's, be revised to account for structural areas susceptible to WFD* .

- Appendix 1, Paragraph 4a: this paragraph refers to Appendix 1, Paragraph 2c, where the original document contained an exception which dealt with a relaxation of the limit load requirements for airplanes not certified to current/ 25.571 standards. This exception has been removed from the proposed text, and should be reinstated.

- Appendix 2, Paragraph 1c: the second sentence states *Since a few cracks of a size which may not be reliably detected by Non Destructive Testing (NDT) can cause unacceptable reduction in the structural strength below the residual strength requirements of the damage tolerance regulations...* . This should be changed to read *Since a few cracks of a size which may not be reliably detected by Non Destructive Testing (NDT) can cause unacceptable reduction in the residual strength of the structure...* .

- Appendix 2, Paragraph 1c: the last sentence states *The manufacturers should conduct evaluations...* . This should be changed to read *The manufacturers, in conjunction with the operators, should conduct evaluations...* .

- Appendix 2, Paragraph 2b (1) (c): frames are already mentioned in (a) and therefore should be deleted or left as a stand alone item in (c)

- Appendix 2, Paragraph 2c (2): states *Each susceptible area should be evaluated for a discrete source damage event due to uncontained failure of engines, fan blades, and high-energy rotating machinery* . The industry recommendation allowed a risk evaluation to determine the areas requiring a discrete source damage evaluation. This should therefore be changed to read *Each susceptible area should be evaluated for a discrete source damage event due to uncontained failure of engines, fan blades, and high-energy rotating machinery, unless it has been demonstrated that the risk due to such an event does not exceed an acceptable level* .

### 4.2.2 Interpretation of Text

The following comments are questions regarding the interpretation of wording, phrases or intent.

- Paragraphs 7, 8 & 9: these Paragraphs are already covered by other regulatory material such as ADs, proposed ACs, and proposed NPRMs. What is the FAA s intent in including these paragraphs here?

- Appendix 2: this Appendix replaces the previous Appendix 2, which contained a list of published SSID programs. Will a future revision to this AC contain a similar list in an Appendix 3?

- Appendix 2, Paragraph 2.b.(1)(e): states "*other pressure bulkhead attachment to skin and web attachment to stiffeners and pressure decks (MSD, MED)*". What does this mean? This issue should be examined in the context of the changes shown in Section 5.2 of this report.

- Appendix 2, Paragraph 2c: what is meant by the term "*test-to-structure factors*" in the last sentence?

- Appendix 2, Paragraph 2e: the intent of this section on period of evaluation validity requires clarification. One possible interpretation is that the initial evaluation will impose a service life on the airplane which can only be extended by additional evaluation. Also, this extended service life is only valid providing the maintenance requirements of the WFD program are met. The AAWG believes that this is the correct interpretation of the text and the FAA should make it clear in the AC Text.

#### 4.2.3 Additional ATA/AIA Comments

Comments were also solicited by the AAWG from ATA/AIA members, in order to allow input from operators not participating in the AAWG. The concerns and queries raised by ATA/AIA members regarding AC 91-56A that were not addressed by the AAWG review were as follows:

- Our understanding of the SSIP program implementation at half design service goal (Paragraph 6, Reference [4]) and WFD inspection program implementation at three quarters design service goal (Paragraph 10, Reference [4]) is that the OEM will have a program drafted by that time. It is our understanding that airplanes will not be inspected by that time. To more clearly make the distinction between when a SSIP program needs to be drafted and when it needs to accomplished, we request the wording to Paragraph 6 more closely parallel Paragraph 10, Reference [4]. Replace "*the program should be initiated no later than the time when the high-time or high-cycle airplane in the fleet reaches one half its design service goal*", with "*development of the program should be initiated no later than the time when the high-time or high-cycle airplane in the fleet reaches one half of its design service goal*".

- We are unclear as to whether or not the WFD inspection program will be applicable to all airplanes as they reach a threshold or whether the WFD will be implemented as a sampling program. Note the recommendations of this report advocate a WFD inspection program applicable to all airplanes above a threshold. No sampling programs are allowed.

- The development of new NDI techniques and procedures is a critical part of the WFD program, and is possibly the weak link. More R&D is needed in the NDI area to provide reliable inspection methods required to detect "small cracks" (on the order of .020 inches) necessary for WFD control. Since this is presently beyond NDI large area capability, we anticipate that once MSD/MED is identified in any structure, extensive modification will be required prior to further operation.

- We must emphasise that the success of this program is dependent upon the joint efforts of the OEMs and operators. We advocate and encourage greater interchange of the technical data generated by the OEMs in compliance with this Advisory Circular. This should be an added explicit requirement contained within the Advisory Circular, *i.e.* a forum should be established for the dissemination of such data to the operators.

### *4.3 DEFINITIONS*

An important aspect of the problem of aging airplanes is the terminology used in discussing the subject. The definitions for certain criteria and their relationships can radically change the concepts of widespread fatigue damage and continuing structural integrity.

Following the Aloha Airlines accident of 1988, the FAA initiated rulemaking to revise FAR 25.571 in order to address shortcomings found as a result of the accident investigation. These revisions dealt specifically with the addition of a requirement for fatigue test evidence for new certifications to address the possibility of widespread fatigue damage. The FAA was assisted in this process by an AIA TARC committee (TC 218-3) and Technical Oversight Group RE: Aging Aircraft (TOGAA). Appropriate changes to the regulations were proposed in 1992, and were published as NPRM 93-9, which included a number of definitions of criteria pertaining to widespread fatigue damage.

In a separate regulatory activity under the auspices of the ARAC, a working group of the TAEIG submitted a revision of AC 91-56 that addressed widespread fatigue damage in the existing fleet. This document, which was completed in 1993, represented a harmonized position accepted by the technical experts of the American and European aerospace industry, the FAA and the JAA. However, the revised AC contained a different set of definitions to those proposed in 1992 and contained in NPRM 93-9. Although the differences were of minor textual importance, the changes made to the definitions were considered technically significant. Nevertheless, the 1993 definitions remained essentially unchanged over the following five years, despite being revisited during two subsequent harmonization tasks.

As part of the initial activities of the AAWG, the established ARAC developed definitions were reviewed and found to remain clear and technically valid. This view was unanimously endorsed by the TAEIG, which recommended that NPRM 93-9 and the accompanying draft AC be changed to reflect the ARAC definitions. After some discussion, the industry position on the definitions was accepted by the FAA and published in Amendment 96 to FAR Part 25 on April 30, 1998.

The approved ARAC definitions are given immediately following this paragraph. It is urged that any future publications on the subject of widespread fatigue damage should include, or at least reference this standard terminology, in order to avoid possible confusion within the industry.

<u>Damage Tolerance</u> is the attribute of the structure that permits it to retain its required residual strength without detrimental structural deformation for a period of use after the structure has sustained specific levels of fatigue, corrosion, accidental or discrete source damage.

<u>Widespread Fatigue Damage</u> (WFD) in a structure is characterized by the simultaneous presence of cracks at multiple structural details that are of sufficient size and density whereby the structure will no longer meet its damage tolerance requirement (*i.e.* to maintain its required residual strength after partial structural failure).

Multiple Site Damage (MSD) is a source of widespread fatigue damage characterized by the simultaneous presence of fatigue cracks in the same structural element (*i.e.* fatigue cracks that may coalesce with or without other damage leading to a loss of required residual strength).

Multiple Element Damage (MED) is a source of widespread fatigue damage characterized by the simultaneous presence of fatigue cracks in similar adjacent structural elements.

In addition, the AAWG proposes the adoption of the following terminology during discussion of programs to ensure continuing structural integrity:

Fatigue Crack Initiation is that point in time when a finite fatigue crack is first expected.

Point of WFD is a point reduced from the average expected behavior, i.e. lower bound, so that operation up to that point provides equivalent protection to that of a two-lifetime fatigue test.

Monitoring Period is the period of time when special inspections of the fleet are initiated due to an increased risk of MSD/MED, and ending when the point of WFD is established.

Design Service Goal (DSG) is the period of time (in flight cycles/hours) established at design and/or certification during which:

1. The principal structure will be reasonably free from significant cracking
2. Widespread fatigue damage is not expected to occur.

Extended Service Goal (ESG) is an adjustment to the design service goal established by service experience, analysis, and/or test during which:

1. The principal structure will be reasonably free from significant cracking
2. Widespread fatigue damage is not expected to occur.

Furthermore, certain terminology has been considered by past working groups in relation to the problem of WFD, but was not used in the final ARAC definitions. The following terms have been previously identified as being open to misinterpretation, and should be avoided, or defined carefully if their use is essential.

Threshold has been used in various contexts, such as

- Fatigue Threshold, which may be defined as the first typical fatigue crack in the fleet for that element .

- Inspection Threshold, which may be defined as the start of supplemental inspections for WFD . The AAWG believes that the real meaning of WFD in this context is MSD/MED.

Onset has been used as an alternative to Threshold, although the simultaneous use of both terms may cause confusion.

Sub-Critical has been used in relation to certain fatigue cracks. However, this may require clarification of what are critical fatigue cracks with reference to occurrence of WFD.

## 4.4 MONITORING PERIOD

The Monitoring Period is a concept that could be used in a number of situations where MSD/MED crack growth is detectable before the structure loses its required residual strength. Figure 4.4.1 is included to depict the differences between local damage crack growth and MSD/MED crack growth. This figure acknowledges the interaction and accelerated crack growth and rapidly decreasing residual strength expected in MSD/MED situations. It also indicates that while the MSD/MED crack growth and residual strength degradation occurs in a more rapid sense, it also is expected to occur later in the life of a given area of structure compared to expected cracking due to local damage. The Supplemental Inspection Program and the more recent Airworthiness Limitations Instructions were written and intended only to access the structure for local damage. Additional inspections and/or modification programs are required for MSD/MED at some point in the life of the airplane.

Figure 4.4.2 depicts how a Monitoring Period might be established for an area of structure that meets the qualification of detectable MSD/MED damage before it reaches critical length. There are several points that are essential in establishing this period. First is the establishing of the Point of WFD (a point reduced from the average expected behavior). This point, beyond which the airplane may not be operated without further evaluation, is established so that operation up to that point provides equivalent protection to that of a two-lifetime fatigue test. The determination of equivalence between test evidence and actual airplane expected life is a subject of discussion between the OEM or STC holder and the regulator. Repeat inspection intervals are established based on the length of time from detectable fatigue cracks to the average WFD (average behavior) divided by a factor. Several opportunities must be provided to detect cracking between fatigue crack initiation and the Point of WFD.

Figure 4.4.3 depicts the antithesis of the previous statement by showing an example of a situation where a Monitoring Period definitely can not be used. Where the situation in Figure 4.4.3 actually exists, the only recourse would be to modify the structure before significant cracking occurs in the fleet.

In section 7.1.3, a number of instances where MED/MSD conditions have been identified in the transport category fleet are discussed. These instances have been identified through the ongoing inspection, maintenance, and restoration activities of the operator community. These inspection, maintenance, and restoration activities have been and will continue to be invaluable in detecting MSD/MED in the fleet.

In Figure 4.4.2, the contribution to safety of these ongoing-programmed inspections has been recognized under the heading of "Normal Inspection Programs." Normal inspections include Maintenance Program, CPCP, SSID, and other mandatory and non-mandatory activities accomplished on the airplane.

While a Type Design holder and/or operator may acknowledge existing inspections and incorporate new inspections as part of the WFD audit process, no further rulemaking on the separate programs which make up the "Normal Inspection Programs" should be required or mandated.

There are a number of general conditions and details that must be met in order that a monitoring period concept can be used. These conditions are:

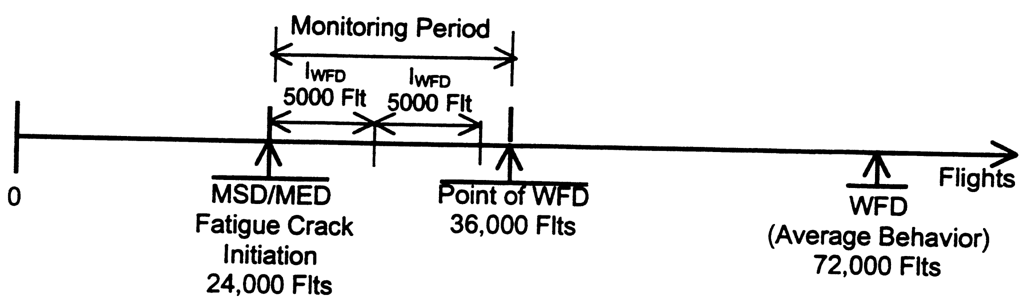
- No airplane may be operated beyond the defined Point of WFD without modification or part replacement.
- The first special inspections, to occur in the monitoring period, should be in line with the estimation of fatigue crack initiation.
- To use a monitoring period for a detail suspected of developing MSD/MED, it must be determined that inspections will reliably detect a crack before the crack becomes critical. If a crack cannot be reliably detected, a monitoring period cannot be used.
- By empirical analysis, evaluation of test evidence and/or evaluation of in-service data, the inspection requirements will be defined for application during the monitoring period.
- The purpose of these inspections is to collect data for reassessment of WFD parameters and to maintain structural integrity (e.g., acceptable level of risk during the monitoring period). Inspections within the monitoring period are mandatory on every airplane as well as reporting of inspection results.
- In the case of MSD or MED findings, the Point of WFD will be re-established in accordance to the inspection results. The area of concern will be repaired following a detailed inspection of adjacent areas using NDI technology that will detect small cracks with a high degree of confidence. The remaining airplanes may be operated up to the revised Point of WFD, with application of a revised monitoring program. Prior to the Point of WFD, the airplane must be repaired, modified, or retired.
- If no MSD/MED cracking is detected by the time the high time airplane reaches the predicted Point of WFD, the predicted Point of WFD could be re-evaluated and the special inspection program may be continued after revalidation.
- The monitoring period will terminate at the point in time at which there is sufficient findings to confirm a MSD/MED problem exists and/or the Point of

WFD is reached. This will be recommended with the assistance of the STG using an established process.

The AAWG reviewed several examples of service actions that have been developed as a result of the development of MSD/MED cracks in both service and test. The following are typical values that can be expected for monitoring periods used in fuselage type structure.

| | | |
|---|---|---|
| WFD (Average Behavior) | = | 72,000 Flights |
| $I_{WFD}$ | = | 5,000 Flights |
| Point of WFD | = | 36,000 Flights |
| MSD/MED Fatigue Crack Initiation | = | 24,000 Flights |

***GRAPHICALLY THIS WOULD LOOK LIKE THIS***



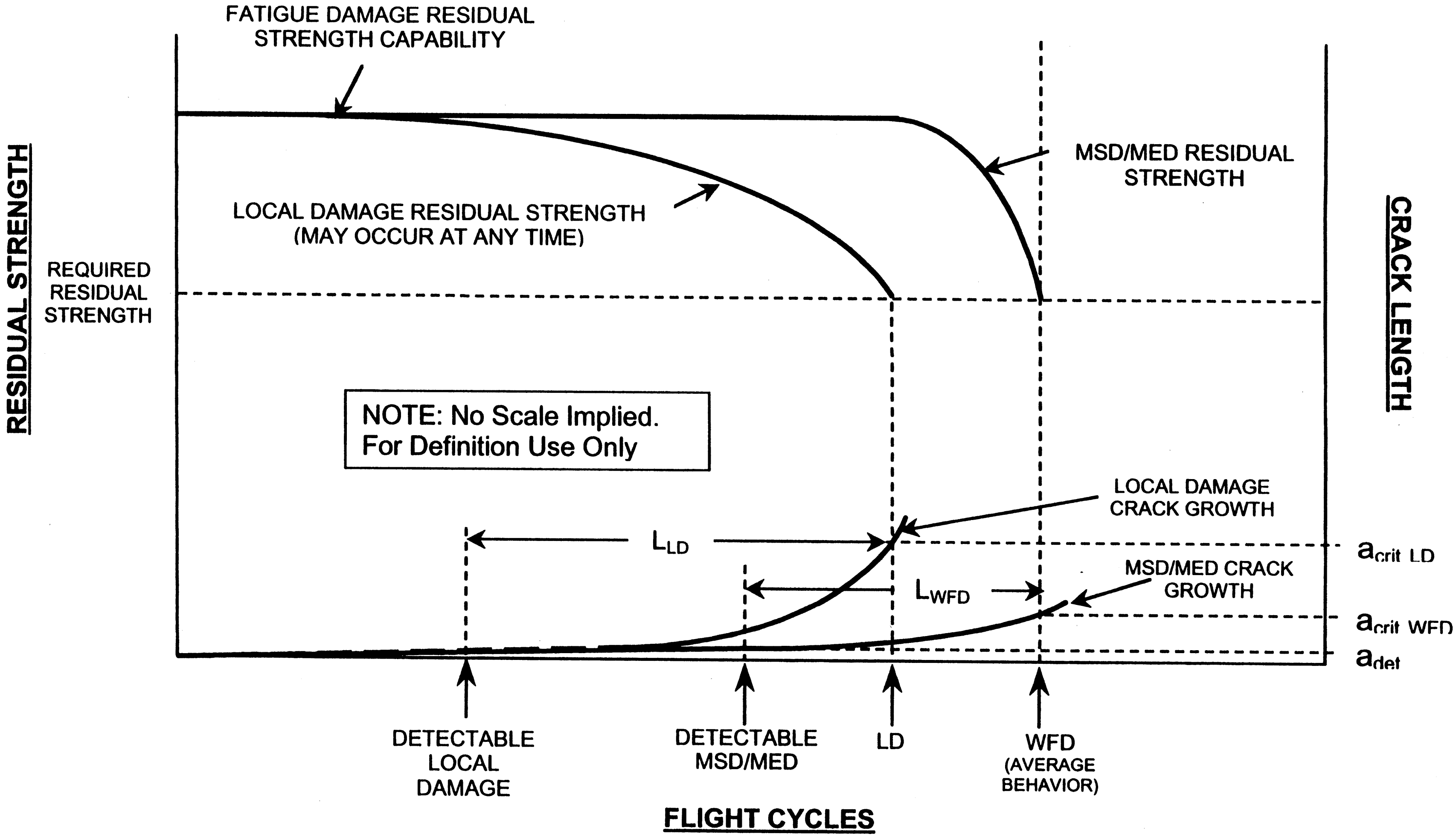



**Fig. 4.4.1: Difference Between Local Damage Behavior and MSD/MED Behavior for a Typical Detail**

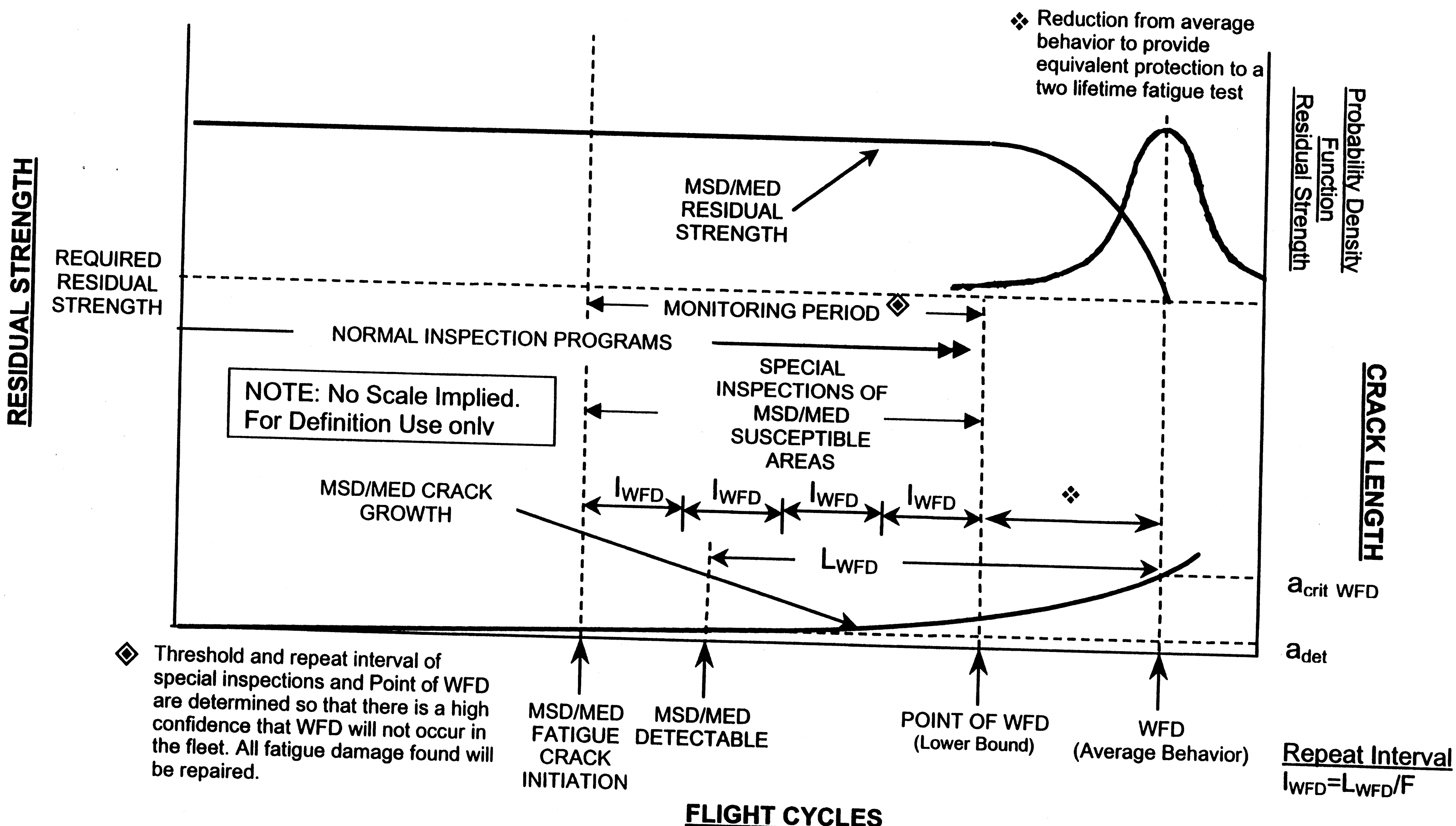



**Fig. 4.4.2: Determination of the Monitoring Period for the Airplane Fleet**



A REPORT OF THE AAWG
RECOMMENDATIONS FOR REGULATORY ACTION TO PREVENT

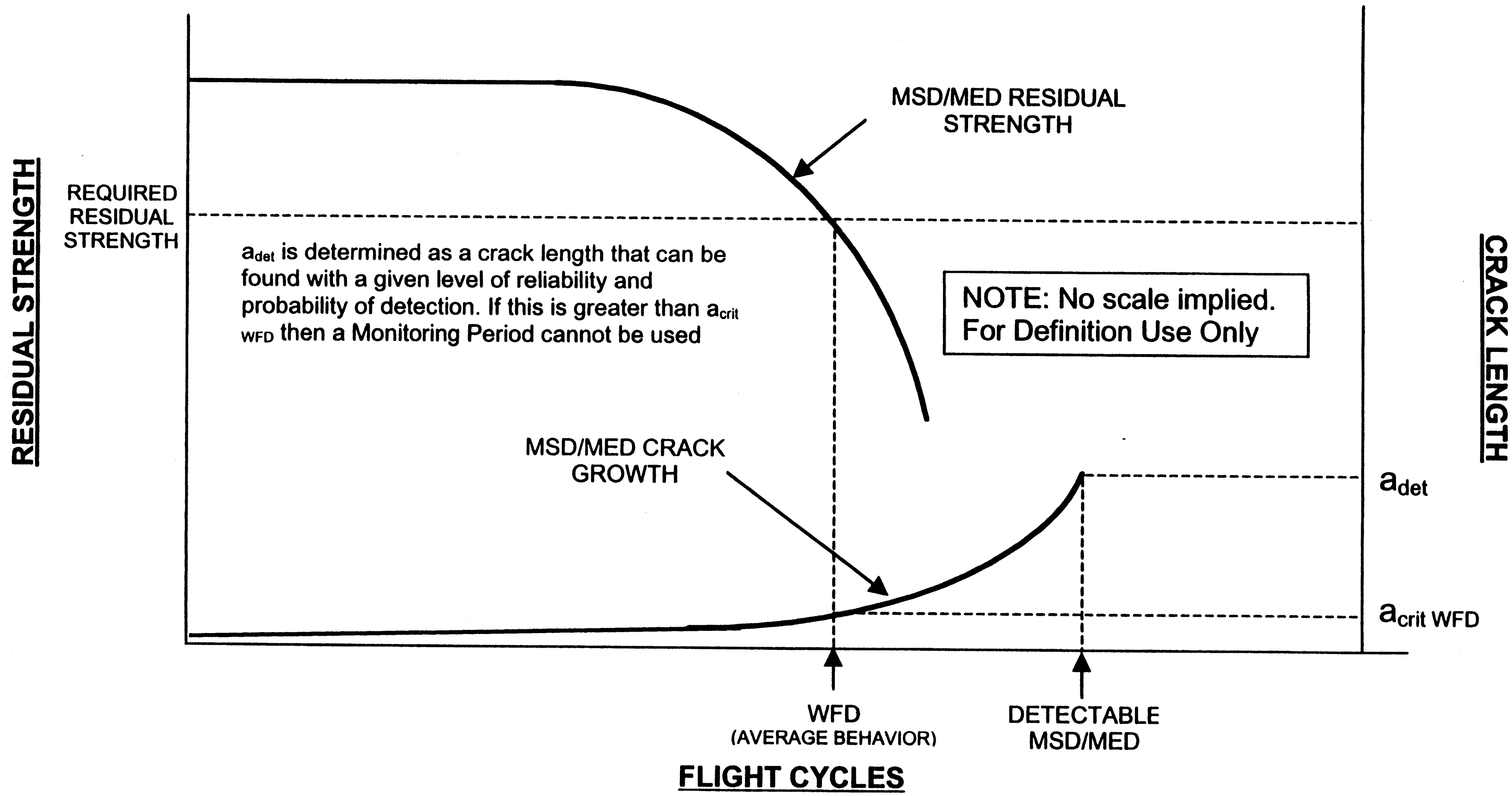



**Figure 4.4.3: Condition Where Monitoring Period Cannot Be Used**

## 4.5 PROPRIETARY DATA ISSUES

The following statement was developed by the AAWG to provide guidance to individual working group members on how Proprietary Data issues would be handled.

The AAWG, in evaluating the need for and extent of research and development for widespread fatigue damage, will be collecting data from a variety of sources including national research organizations, private research groups, and airplane manufacturers. In the process, it is not the intent of the AAWG to collect information that would constitute a breach of individual corporate proprietary data rules. Individuals representing various entities should clear, prior to submittal, all transfers of information to the AAWG with their respective officers in charge of proprietary data. Data given to the AAWG may be published, attributed to source and subject to public scrutiny.

# 5.0 TECHNICAL ISSUES

## 5.1 AUTHORITIES REVIEW TEAM ISSUES AND ACTION

The ARAC Tasking required that a team of technical experts from the regulators review the technical program, developed by the AAWG. The purpose of this review was to validate the approach adopted by the AAWG. This review occurred in the March 1998 Gatwick UK meeting. The team, hereafter known as The Authorities Review Team, or ART, consisted of:

| | |
|---|---|
| John Bristow, Chair | CAA-UK |
| Bob Eastin | NRS Fatigue and Fracture, FAA |
| Brent Bandley | Aerospace Engineer, FAA |
| Stephane Boussu | DGAC - France |

The ART reviewed the approach of the AAWG with respect to the tasking as well as presentations on OEM methodologies. John Bristow, chair, expressed his thanks for participation of the AAWG-TPG at the ART Review. He expressed that while there were certain things that needed to be addressed, the ART felt that the team was properly composed and heading in the right direction.

The ART did find areas within the scope of the program that they needed further development from both a regulatory and a technical viewpoint. A total of twenty issues were presented to the AAWG for resolution. The AAWG evaluated each of the issues and then assigned action to resolve each issue. The following table delineates the issues and actions that were assigned and completed.

| ITEM | ISSUE | Final Report Section |
|---|---|---|
| 1 | The ART would like to see a more immediate focus on validation of OEM methodologies through round-robins etc. and a defocus of R&D review. | 8.6 |
| 2 | The ART would like to see more information related to residual strength testing related to WFD. | Sec 6.1.5 |
| 3 | The ART would like an explanation of Objective Evidence specifically what the meaning of Qualitative vs. Quantitative is. | Explain at next review |
| 4 | The ART believes that there is sufficient data available to determine the state of the fleet WRT MSD/MED. For example, the ART wants the AAWG to review SDR data in coming to conclusions regarding the health of the fleet. | 7.0 |
| 5 | The ART would like to see more real-life examples. | 7.0 |
| 6 | The ART wants more information on STCs and how the issue might be addressed. | 5.6 |
| 7 | The ART does not understand the issue of Restraints in getting fleet data. | 7.0 |

| ITEM | ISSUE | Final Report Section |
|---|---|---|
| 8 | The ART would like the establishment of a baseline detectable flaw to consider in-service constraints including the requirement of wide area inspections and would like that information by the end of April 1998. | 6.2 |
| 9 | The ART wants more information WRT the DPD presentation on monitoring period. | 4.4 |
| 10 | The ART needs justification for the removal of discrete source damage. | 5.3 |
| 11 | The ART feels that if the existing maintenance program is adequate to detect MSD/MED, then that program should be mandated. | 4.1 |
| 12 | The ART will look for a recommendation on how to overcome the shortfall in technology. | 6.0 |
| 13 | The ART will require a consistent usage of terminology and definitions by the AAWG | 4.3 |
| 14 | The ART will need a significantly higher level of technical presentation at the next review. | Agreed |
| 15 | The ART desires to see on a fleet by fleet basis, timelines delineating when the analysis is complete, when the changes to the maintenance programs (e.g. mandatory mods, SSID changes etc.) will be complete, and when the programs need be implemented in the fleet. | 9.0/10.0 |
| 16 | The ART will require a revisit to the at risk fleets. They feel freighters need to be included, the logic behind the division at 1/2 DSG is not clear (needs to be supported by fleet evidence), and that there may be other airplanes needed in priority 2 by virtue of derivative design. They would also like to see the number of airplanes exceeding 100% DSG and the actual DSG for each Aircraft fleet. | Table 9.1 |
| 17 | The ART requires additional information regarding Step 1.1 of The Airplane Evaluation Process . They would like additional definitions developed and an additional step added. | Figure 1.1 |
| 18 | The ART would like to understand how allowable lead times for modifications are established. | 9.2 |
| 19 | The ART needs additional data WRT how life limits would be imposed and how the handling of a non-compliance action occurs. | 10.0 |
| 20 | While the ART concurs that the monitoring period is an appropriate means to work this problem, the developments of appropriate constraints are necessary to make the approach viable. | 4.4 |

The Report Section numbers refer to where the issues are discussed in detail.

## *5.2 AREAS SUSCEPTIBLE TO MSD/MED*

Susceptible structure is defined as that which has the potential to develop MSD/MED. This structure has the characteristics of similar details operating at similar stress levels where structural capability could be significantly degraded by the presence of multiple cracks.

Figures 5.1 through 5.16 illustrate major sections of airplane structure, and construction typical of those areas, which industry experience has shown to be susceptible to MSD/MED. The illustrations shown are typical and do not show all types of construction or structural details, which may be peculiar to an airplane model. Some model specific examples may be best illustrated by a combination of these examples. Additional areas of the model specific structure should be assessed if indicated by service or test experience.

MSD and/or MED can also occur in structure that does not have a major impact on the continued safe operation of an airplane. For example MSD cracking of a web adjacent to a stiffener may not be any more significant than a single fatigue crack. Also, it is not expected that secondary structure will be included in the WFD assessment.

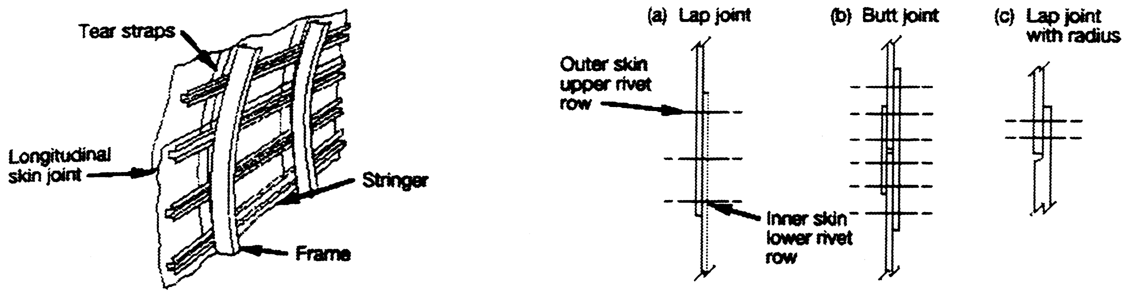
Susceptible areas are characterized by similar structural details operating at uniform stress levels. There are many significant structural problems that can occur in airplane structure due to fatigue cracking but they typically <u>are not</u> precursive forms WFD. Examples are:

- CHRONIC INSERVICE FATIGUE PROBLEMS, which left undetected or uncorrected, could lead to a significant failure.
- MULTIPLE PARALLEL CRACKS which grow parallel to each other and do not have the potential to link-up
- ELEMENTS IN COMMON such as a fuselage bulkhead (skin, web, and cap) or a wing spar (skin, cap, and web). Fatigue cracking of a single element if left undetected or uncorrected can ultimately lead to fatigue cracking of all three elements at a common location. Service actions and AD s should be adequate.
- LINK-UP OF INDEPENDENT FATIGUE PROBLEMS in adjacent but not similar structural elements (not MED) can grow, if not corrected, until they link-up resulting in a very significant loss in residual strength. STG service action review should mandate corrective action.

The priority to be assigned to each susceptible structural item to be evaluated for widespread fatigue damage will be dependent upon the individual airplane model. The OEM or STC holder should assess these properties for each airplane model on the basis of in-service experience, test and/or analysis. It is recommended that this survey be performed at the start of the evaluation.

The list of structure potentially susceptible to MSD/MED first appeared in the 1993 report of the Industry Committee on Widespread Fatigue Damage. Additional areas and details have been added as a result of further review of service experience. Additionally, details of crack locations have been clarified.

| STRUCTURAL AREA | FIGURE |
|---|---|
| • Longitudinal Skin Joints, Frames, and Tear Straps (MSD/MED) | 5.1 |
| • Circumferential Joints and Stringers (MSD/MED) | 5.2 |
| • Lap joints with Milled, Chem-milled or Bonded Radius (MSD) | 5.3 |
| • Fuselage Frames (MED) | 5.4 |
| • Stringer to Frame Attachments (MED) | 5.5 |
| • Shear Clip End Fasteners on Shear Tied Fuselage Frames (MSD/MED) | 5.6 |
| • Aft Pressure Dome Outer Ring and Dome Web Splices (MSD/MED) | 5.7 |
| • Skin Splice at Aft Pressure Bulkhead (MSD) | 5.8 |
| • Abrupt Changes in Web or Skin Thickness Pressurized or Unpressurized Structure (MSD/MED) | 5.9 |
| • Window Surround Structure (MSD, MED) | 5.10 |
| • Over Wing Fuselage Attachments (MED) | 5.11 |
| • Latches and Hinges of Non-plug Doors (MSD/MED) | 5.12 |
| • Skin at Runout of Large Doubler (MSD) Fuselage, Wing or Emp | 5.13 |
| • Wing or Empennage Chordwise Splices (MSD/MED) | 5.14 |
| • Rib to Skin Attachments (MSD/MED) | 5.15 |
| • Typical Wing and Empennage Construction (MSD/MED) | 5.16 |



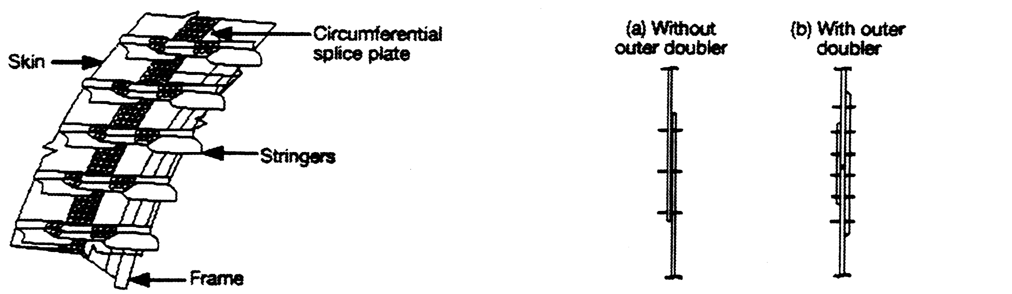

Type and possible location of MSD and MED

- MSD longitudinal skin joint
  - Lap joint
    - Outer skin upper rivet row
    - Inner skin lower rivet row
  - Butt joint
    - Skin outer rivet rows
    - Doubler inner rivet rows
  - Lap joint with radius
    - In radius
- MED—frame
  - Stress concentration areas
- MED—tear straps
  - Critical fastener rows in the skin at tear strap joint

Service or test experience of factors that influence MSD and MED (examples)

- High stress—misuse of data from coupon test
- Corrosion
- Disbond
- Manufacturing defect
  - Surface preparation
  - Bond laminate too thin
  - Countersink, fastener fit
- Design defect—surface preparation process

Figure 5.1 Longitudinal Skin Joints, Frames, and Tear Straps (MSD/MED)



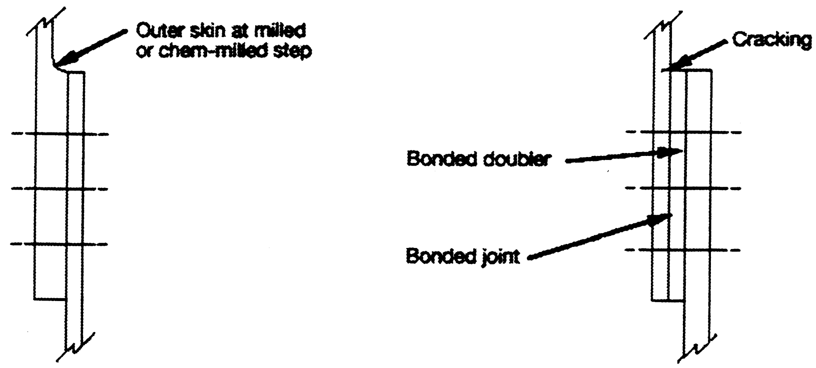

Type and possible location of MSD/MED

- MSD—circumferential joint
  - Without outer doubler
    - Splice plate—between and/or at the inner two rivet rows
    - Skin—forward and aft rivet row of splice plate
    - Skin—at first fastener of stringer coupling
  - With outer doubler
    - Skin—outer rivet rows
    - Splice plate/outer doubler—inner rivet rows
  - MED—stringer/stringer couplings
    - Stringer—at first fastener of stringer coupling
    - Stringer coupling—in splice plate area

Service or test experience of factors that influence MSD and/or MED (examples)

- High secondary bending
- High stress level in splice plate and joining stringers (misuse of data from coupon test)
- Poor design (wrong material)
- Underdesign (over-estimation of interference fit fasteners)

Figure 5.2 Circumferential Joints and Stringers (MSD/MED)



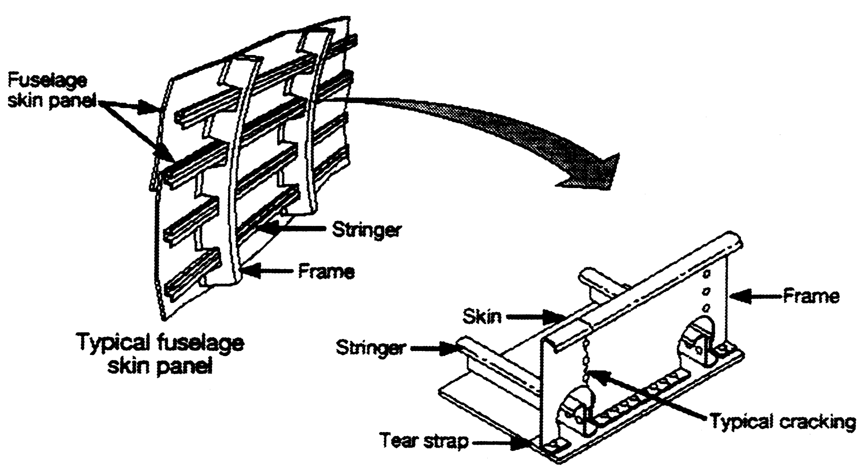

Type and possible location of MSD and MED

- MSD—abrupt cross section change
- Milled radius
- Chem-milled radius
- Bonded doubler runout

Service or test experience of factors that influence MSD and MED (examples)

- High bending stresses due to eccentricity

Figure 5.3 Lap joints with Milled, Chem-milled or Bonded Radius (MSD)



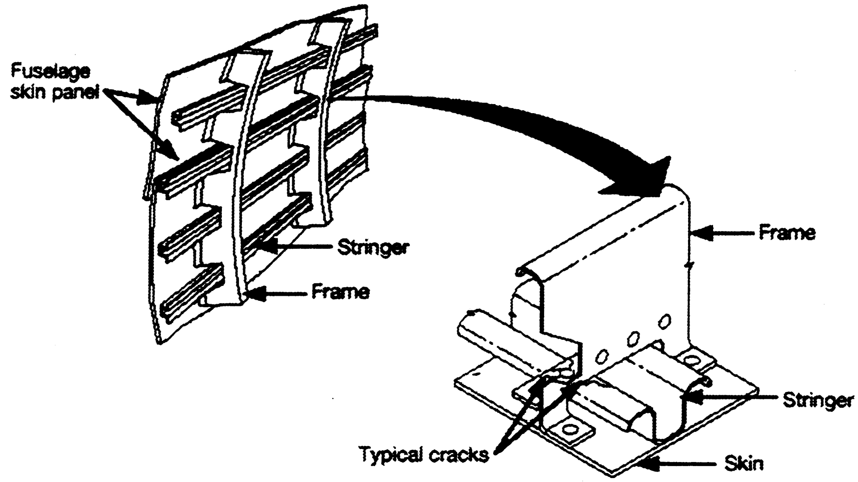

Type and possible location of MSD/MED

- MED—the cracking of frames at stringer cutouts at successive longitudinal locations in the fuselage. The primary concern is for those areas where noncircular frames exist in the fuselage structure. Fractures in those areas would result in panel instability.

Service or test experience of factors that influence MSD and/or MED (examples)

- High bending—noncircular frames
- Local stress concentrations
  - Cutouts
  - Shear attachments

Figure 5.4 Fuselage Frames (MED)



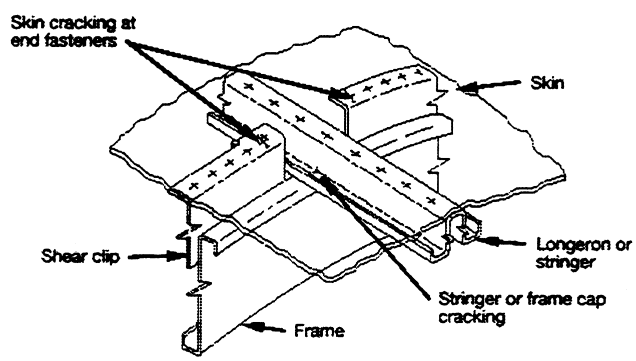

Type and possible location of MED

- MED—any combination of fracture of frames, clips, or stringers, including the attachments, resulting in the loss of the shear tie between the frame and stringer. This condition may occur at either circumferential or longitudinal locations at fuselage frame/stringer intersection.

Service or test experience of factors that influence MSD and/or MED (examples)

- Poor load path connection

Figure 5.5 Stringer to Frame Attachments (MED)



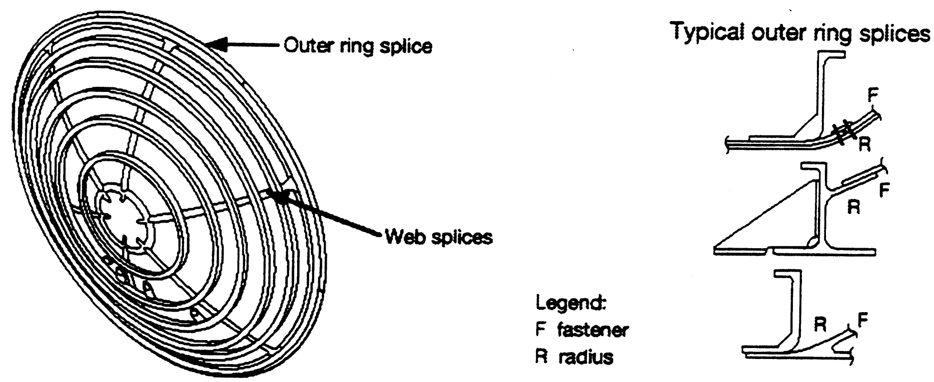

Type and possible location of MSD and MED

- MSD—skin at end fastener of shear clip
- MED—cracking in stringer or longeron at frame attachment
- MED—cracking in frame at stringer or longeron attachment

Service or test experience of factors that influence MSD and MED (examples)

- Preload
- Localized bending due to pressure
- Discontinuous load path

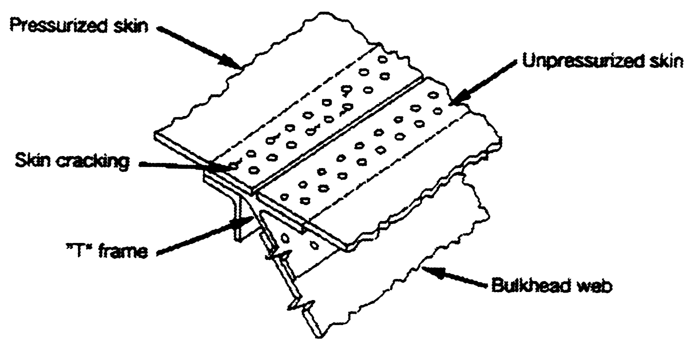
Figure 5.6 Shear Clip End Fasteners on Shear Tied Fuselage Frame (MSD/MED)




Type and possible location of MSD/MED
- MSD/MED—outer ring splice
  - Attachment profiles—at fastener rows and/or in radius area
- MED—web splices
  - Bulkhead skin and/or splice plates—at critical fastener rows

Service or test experience of factors that influence MSD and/or MED (examples)
- Corrosion
- High stresses—combined tension and compression
- High induced bending in radius
- Inadequate finish in radius—surface roughness

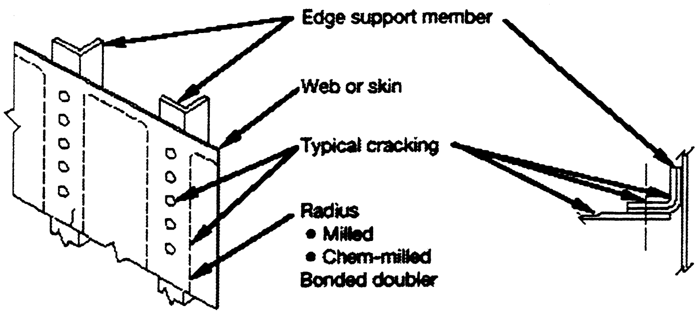
Figure 5.7 Aft Pressure Dome Outer Ring and Dome Web Splices (MSD/MED)




Type and possible location of MSD and MED
- MSD—skin at end fastener holes

Service or test experience of factors that influence MSD and MED (examples)
- Shell discontinuous induced bending stresses
- High load transfer at fastener

Figure 5.8 Skin Splice at Aft Pressure Bulkhead (MSD)




**Type and possible location of MSD and MED**

Abrupt change in stiffness*
- Milled radius
- Chem-milled radius
- Bonded doubler
- Fastener row at edge support members

Edge member support structure
- Edge member - in radius areas

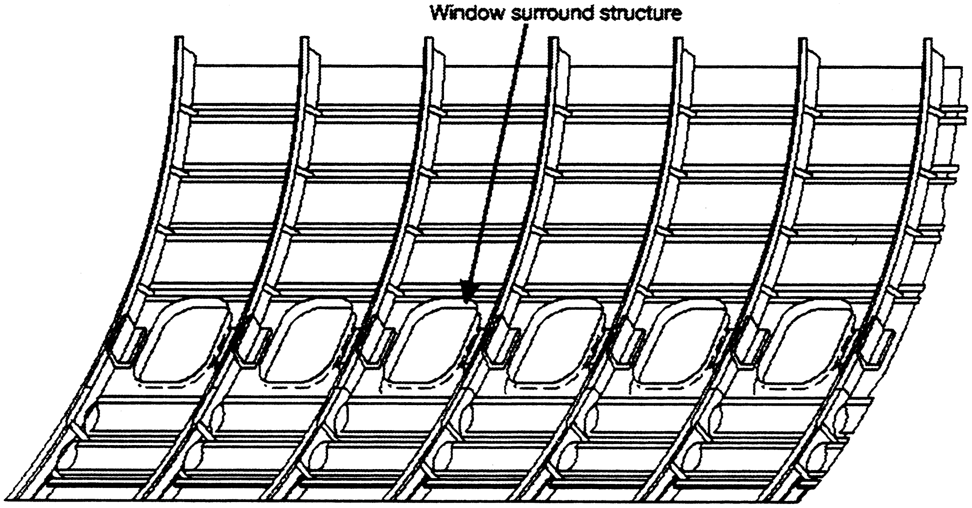
**Service or test experience of factors that influence MSD and MED**

Pressure structure
- High bending stresses at edge support due to pressure

Non-pressure structure
- Structural deflections cause high stresses at edge supports

* Often multiple origins along edge member

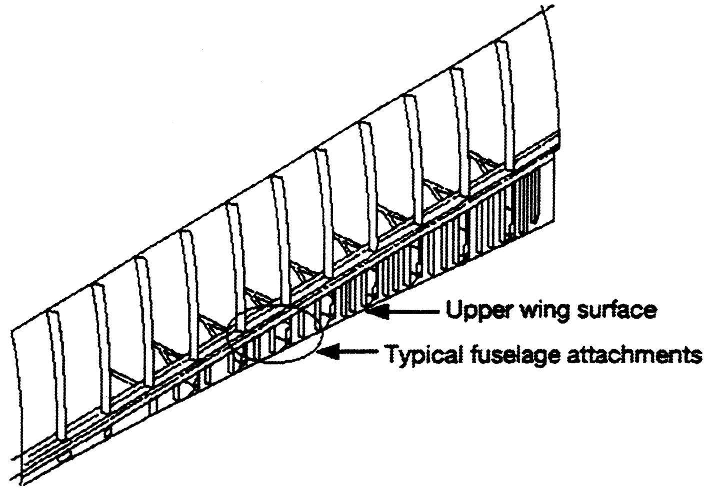
Figure 5.9 Abrupt Changes in Web or Skin Thickness Pressurized or Unpressurized Structure (MSD/MED)




Type and possible location of MSD/MED
- MSD—skin at attachment to window surround structure
- MED—repeated details in reinforcement of window cutouts or in window corners

Service or test experience of factors that influence MSD and/or MED (examples)
- High load transfer

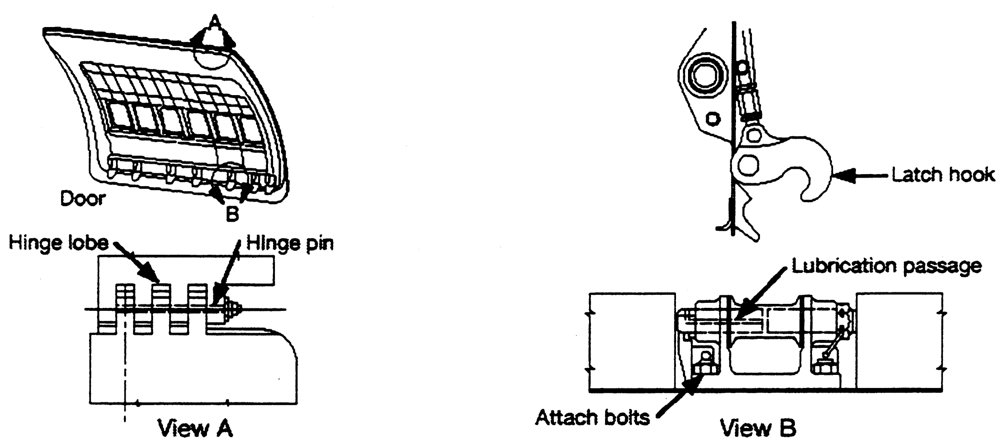
Figure 5.10 Window Surround Structure (MSD, MED)




Type and possible location of MSD/MED
- MED—repeated details in overwing fuselage attachments

Service or test experience of factors that influence MSD and/or MED (examples)
- Manufacturing defect—prestress
- Induced deflections

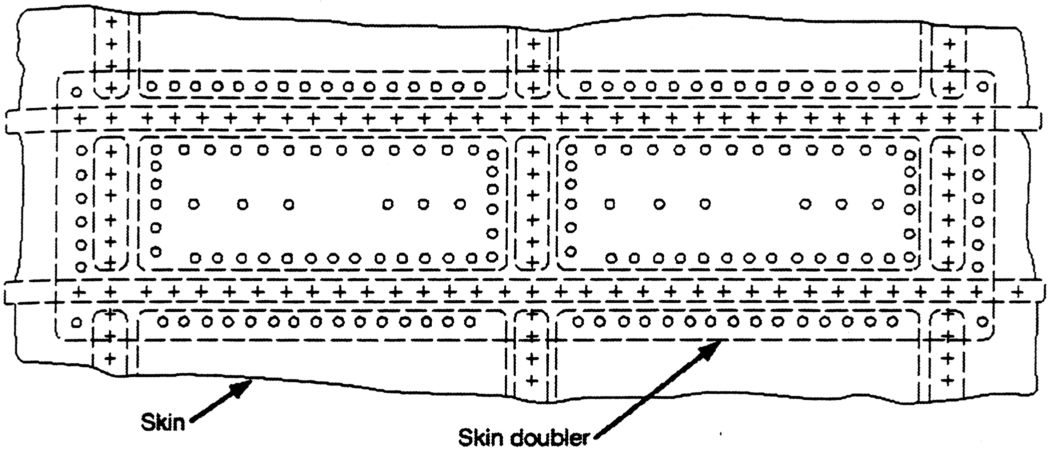
Figure 5.11 Over Wing Fuselage Attachments (MED)




Type and possible location of MSD/MED
- MSD—piano hinge
  - At hinge fastener attachment row
  - In fillet radius
  - Emanating from hole in lobes
- MED—latches
  - In multiple latch hooks
  - At lube channel of latch spool
  - At spool bracket attach bolts (also corrosion)

Service or test experience of factors that influence MSD and/or MED (examples)
- Bending stresses due to fuselage elongation
- High local stress
- Fretting

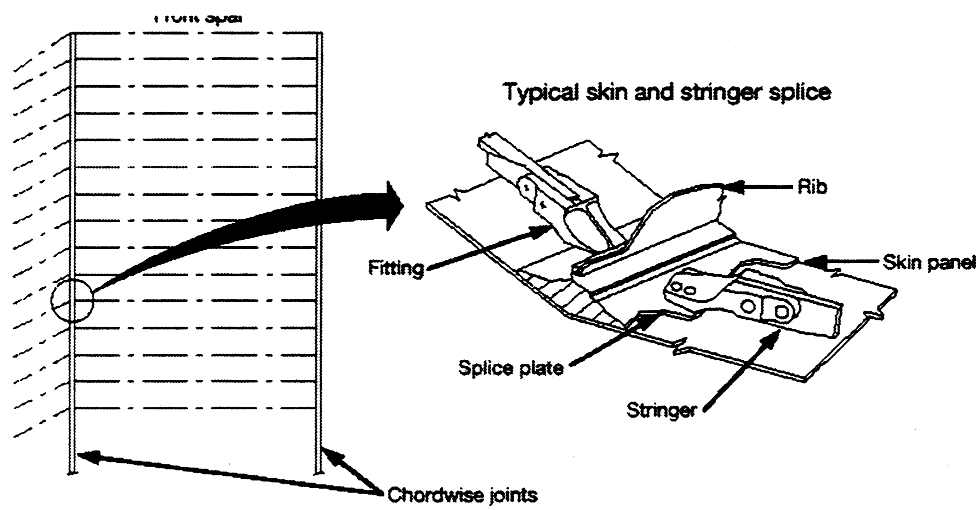
Figure 5.12 Latches and Hinges of Non-plug Doors (MSD/MED)




Type and possible location of MSD/MED
- MSD—cracks initiated at multiple critical fastener holes in skin at runout of doubler

Service or test experience of factors that influence MSD and/or MED (examples)
- High load transfer—high local stress

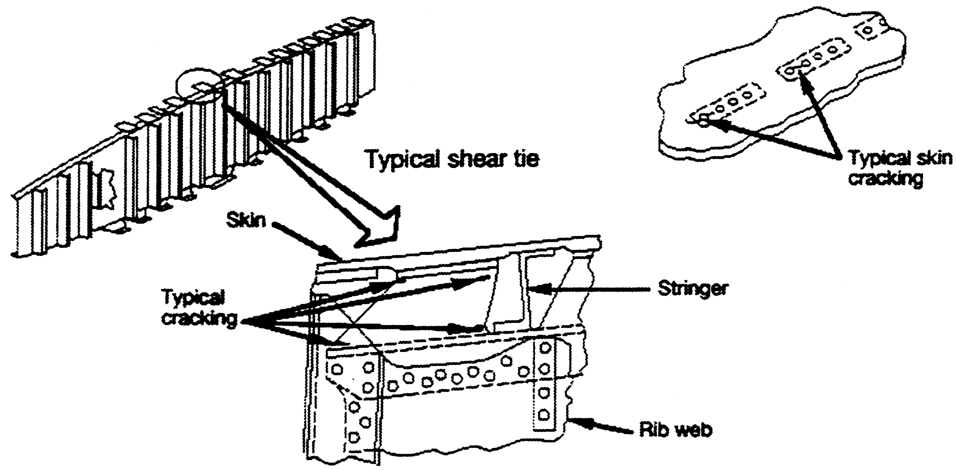
Figure 5.13 Skin at Runout of Large Doubler (MSD) Fuselage, Wing or Empennage




Type and possible location of MSD/MED
- MSD—skin and/or splice plate
  - Chordwise critical fastener rows
- MED—stringer runout of fitting
  - Fatigue-critical fastener holes at stringer and/or fitting

Service or test experience of factors that influence MSD and/or MED (examples)
- High load transfer
- Local bending

Figure 5.14 Wing or Empennage Chordwise Splices (MSD/MED)



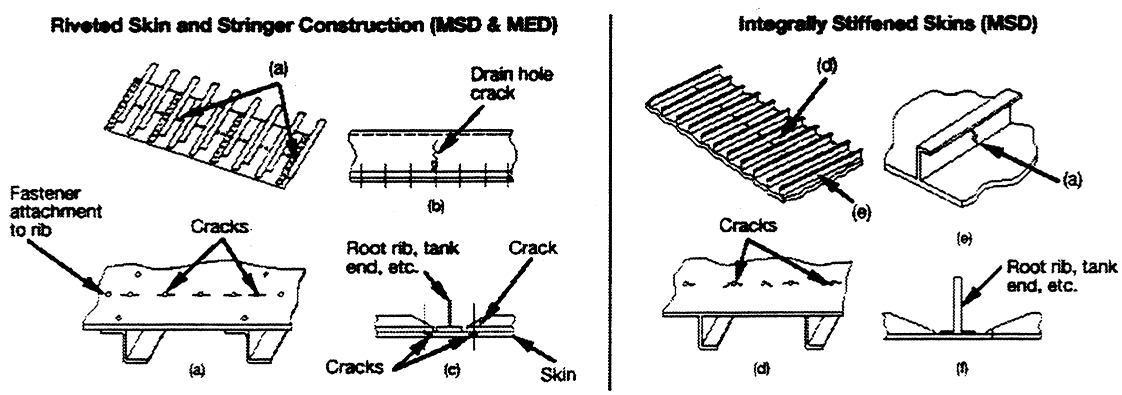

Type and possible location of MSD and MED

- MSD—critical fasteners in skin along rib attachments
- MED—critical rib feet in multiple stringer bays (particularly for empennage under sonic fatigue)

Service or test experience of factors that influence MSD and MED (examples)

- Manufacturing defect—prestress due to assembly sequence
- Sonic fatigue (empennage)

Figure 5.15 Rib to Skin Attachments (MSD/MED)




Inherent fail safe and crack stopper characteristics

- MSD—chordwise cracks link up at
  - a) Rib attachment holes
- MED—
  - b) Drain or vent holes
  - c) Stiffener run-outs at root rib or tank end rib

Do not have inherent crack stopper characteristics of riveted skin and stringer construction

- MSD—Chordwise cracks link up at
  - d) Rib attachment holes
  - e) Drain or vent holes
  - f) Stringer run-outs at root rib or tank end rib
- MED—becomes MSD

Figure 5.16 Typical Wing and Empennage Construction (MSD/MED)

## 5.3 DSD COMBINED WITH MSD

### 5.3.1 Background

In the AAWG report of 1993 Reference [3], a requirement for the consideration of Discrete Source Damage (DSD) was included within the proposed guidelines for the evaluation of WFD, as follows:

> *'If applicable, each WFD susceptible area should be evaluated for a discrete source damage event due to uncontained failure of engines, fan blades and high energy rotation machinery. If the risk due to such an event is not acceptable for the specific area, the characteristic WFD parameters, fatigue crack initiation, MSD/MED propagation, and occurrence of WFD should be evaluated to include this damage source.'*

Of the different types of DSD, only rotor burst was considered. This damage is the only one that could potentially result in scenarios that could interact with MSD/MED. Debris from a high energy event such as an uncontained engine failure has significant potential to degrade the residual strength of structural details susceptible to WFD. Other types of DSD, such as bird impact, do not have the same potential.

The risk due to such a combined event was quantified by the AAWG-TPG for several pre- and post-amendment 45 airplanes, and compared to the required levels in the airworthiness regulations. Six airplane types were included in this study, *viz.*

- Airbus A340
- BAC One-Eleven
- Boeing 727
- Boeing 737
- Boeing DC9/MD-90
- Lockheed L-1011

The results of these comparisons indicate that the generalized combined probability of failure is significantly below that required by the applicable regulations.

### 5.3.2 Technical Approach

Compliance with the current airworthiness regulations covering uncontained engine failures is demonstrated through two different parts of the Federal Aviation Regulations (FAR) and the Joint Aviation Requirements (JAR). In FAR/JAR 25.1309 References [5,6], system failures are assessed through the principle that there should be an inverse relationship between the severity of the effect of the failure on the airplane and the probability of its occurrence, *i.e.*

> *'(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that*
> *(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable; and*
> *(2) The occurrence of any other failure condition which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.'*

In the supporting Advisory Material, the probability of an extremely improbable failure condition is required to be not greater than $10^{-9}$ per flight hour, whilst the improbable failure condition has a probability not greater than $10^{-5}$ per flight hour.

Alternatively, FAR/JAR 25.903 References [7,8] calls for a safety analysis which considers the possible trajectory paths of engine rotor debris relative to critical areas, including damage to primary structure such as the pressure cabin, engine mountings and control surfaces. The rotor debris is modeled as a 'single one-third piece of disc', *viz.*

> *'It should be assumed that the one-third piece of disc has the maximum dimension corresponding to one-third of the disc with one-third blade height and an angular spread of ±3 degrees relative to the plane of rotation of the disc.'*

There is an additional requirement to consider small pieces of debris with an angular spread of ±5 degrees. The AAWG chose to encompass this requirement by considering the one-third piece of disc with an angular spread of ±5 degrees.

In order to demonstrate compliance with this regulation, it must be shown that, in the event of an uncontained engine failure, the risk of a catastrophic structural or systems failure is maintained at some acceptable level, *i.e.*

> *'When all practical design precautions have been taken and the safety analysis made using the engine failure model ... shows that catastrophic risk still exists for some components or systems of the airplane, the level of catastrophic risk should be evaluated. It is considered that the objective of the requirement will have been met if ... there is not more than a 1 in 20 chance of catastrophe resulting from the release of a single one-third piece of disc.'*

There is also a requirement in FAR/JAR 25.571, References [7,8], for the consideration of DSD. However, this regulation does not require consideration of environmental, fatigue or accidental damage in combination with DSD. In the past, regulators have normally accepted static analysis of the remaining structure, involving a 'scalping' cut from rotor debris passing through the structure, as demonstrating compliance with this rule.

In this assessment, the safety targets of $10^{-9}$ probability of failure per flight hour (FAR/JAR 25.1309) and 1 in 20 chance of catastrophe (FAR/JAR 25.903) have been selected to show compliance with the regulations.

### 5.3.3 Analytical Procedure

#### 5.3.3.1 $10^{-9}$ Probability of Failure per Flight Hour

Of all structural configurations, the most critical engine/airframe configuration with respect to the problem of DSD (e.g. potential damage) is that of a rear fuselage mounted engine. For the purposes of this discussion, the MD-90, a twin-engined airplane with the engines mounted in the rear fuselage is used.

An assessment of uncontained engine failure which results in the probability of failure per flight hour is a combination of the following components:

(a)Uncontained engine failure

(b) Phase of Flight

(c) Number of critical disks

(d) Critical spread angle

(e) Trajectory

(f) Critical Time

Based on these components, the Normal probability for a catastrophic airplane failure following a rotor burst is in the order of $4 \times 10^{-11}$ for the MD-90. This probability is calculated in consideration of the following airplane/systems analysis

- Airframe Structure
- Avionics/Instrumentation
- Electrical
- Remaining engine
- Fire Protection
- Flight Controls
- Fuel System
- Hydraulics
- Pneumatics
- Multi System (worst case)

With the computation of a value less than $1 \times 10^{-9}$, any possible interaction of MSD/MED with a discrete source event is non-existent based on today s regulatory standards.

#### ***5.3.3.2 1 in 20 Risk of Catastrophe***

In the 1 in 20 calculation it is assumed that the uncontained engine failure event will occur, such that the probability of failure, $P_{UEF}$, becomes 1.0. The computation of the 1 in 20 risk of catastrophe involves the evaluation of the average risk from the phase of flight, spread angle, and trajectory. For the MD-90, the overall average risk, not considering the presence of MSD/MED is on the order of 0.04500 or 1 in 22.

The incremental effect of the possible presence of MSD/MED on this risk is computed considering the probability of the presence of MSD/MED, phase of flight, spread angle, and trajectory. The estimated total probability of having MSD/MED on an airplane being operated in the neighborhood of it s DSG is about 0.02 (based on a lognormal distribution with a standard deviation of 0.15). The total risk is given by:

R = 0.045 + 0.02*0.045 = 0.0459 or still about 1 in 22

This computation is conservative, based on the fact that if actual spread angles and trajectories were used for the threat of MSD, then the 0.045 would be somewhat reduced. Operation of the airplane would be permissible up until there was a total probability of MSD/MED of about 0.11. This would equate to around a 30% increase in the given DSG without impacting the 1 in 20 certification limit.

### 5.3.4 Environmental and Accidental Damage

The computations of the previous section were limited to a rotor burst scenario. There are other potential sources of damage that could lead to large-scale damage in the presence of MSD or MED. These include environmental degradation and accidental damage (including manufacturing damage).

As a result of the aging airplane activities started in 1988, maintenance programs have been modified to include corrosion prevention and control programs that effectively limit the amount of environmental degradation that can occur between maintenance visits. As part of the recommendations of this report, one element of an effective program to limit potential interaction between MSD/MED and environmental degradation is an effective corrosion control program. With this in place, a potential interaction between MSD/MED and environmental degradation is minimized.

Accidental damage, excluding obvious damage inflected on the ground, can be separated into two separate categories of events. The first type of accidental damage is that that might be caused by a dropped tool or other object, creating some significant but undiscovered damage to the structure. Maintenance programs are generally structured to find such events before they become critical through current scheduled inspections of the SSID or ALI program. This kind of damage is considered as local isolated damage and in general will never interact with MSD/MED damage scenarios. The other form of accidental damage is more of a concern since it in itself can be the source of MSD type events. This form of damage is the result of unapproved methods and procedures used either during manufacturer or maintenance. Damage such as scribe lines placed into structure while trimming adhesives or chemical milling masks are typical of the types of concerns this threat poses. There have been several notable in-service failures associate with this kind of damage. Unfortunately there is no way to predict the occurrence of this kind of damage. When this type of damage is found, it must be aggressively investigated and corrected on all airplanes that could be affected. The inherent fail-safe qualities of the structure should be more than adequate to contain this type of damage if the two-lifetime fatigue test rule is applied.

## *5.4 CERTIFICATION STANDARDS*

Airplanes have been certified to a variety of standards over time with regards to damage sizes considered for residual strength evaluation. These standards have included:

- CAR 4b.270 (b)
  Ref. CAR 4b.270 (b), 1962:
  *Fail safe strength.* It shall be shown by analysis and/or tests that catastrophic failure or excessive deformation, which could adversely affect the flight characteristics of the airplane, are not probable after fatigue failure or obvious partial failure of a single principal structural element.

- FAR 25.571 Pre Amendment 45
  Ref. FAR 25.571 (c), 1967:
  *Fail safe strength.* It must be shown by analysis, tests, or both, that catastrophic failure, or excessive deformation, that could adversely affect the flight characteristics of the airplane, are not probable after fatigue failure or obvious partial failure of a single principal structural element......

- FAR 25.571 Post Amendment 45
  Ref. FAR 25.571 (c), 1978:
  *Damage Tolerance (fail-safe) Evaluation.* The evaluation must include a determination of the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. The determination must be by analysis supported by test evidence and (if available) service experience. Damage at multiple sites due to prior fatigue exposure must be included where the design is such that this type of damage can be expected to occur. The evaluation must incorporate repeated load and static analyses supported by test evidence. The extent of damage for residual strength evaluation at any time within the operational life must be consistent with the initial detectability and subsequent growth under repeated loads. The residual strength evaluation must show that the remaining structure is able to withstand loads (considered as static ultimate loads) corresponding to the following conditions:

- FAR 25.571 Post Amendment 54
  Ref. FAR 25.571 (b), 1980:
  *Damage-Tolerance Evaluation.* The evaluation must include a determination of the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. The determination must be by analysis supported by test evidence and (if available) service experience. Damage at multiple sites due to prior fatigue exposure must be included where the design is such that this type of damage can be expected to occur. The evaluation must incorporate repeated load and static analyses

supported by test evidence. The extent of damage for residual strength evaluation at any time within the operational life must be consistent with the initial detectability and subsequent growth under repeated loads. The residual strength evaluation must show that the remaining structure is able to withstand loads (considered as static ultimate loads) corresponding to the following conditions:

Both CAR 4b.270 (b) and FAR 25.571 Pre-amendment 45 require the applicant to consider that the failure or obvious partial failure of a single principle structural element would not be catastrophic to the airplane. Historically, these fail-safe damage sizes were related to large areas of structure being removed with positive static margins of safety with respect to 80% (CAR 4b and 100% FAR 25.571 Pre-Amendment 45) limit loads. The amount of structure removed was generally determined by a subjective criterion, namely that the structural failure or obvious partial failure represented by the structure removed would be easily detected and repaired before failure of the remaining structure.

The advent of fail-safe designs was a major step towards improved structural reliability and safety. However the fail-safe philosophy was not without its shortcomings. One of those shortcomings was made manifest in the crash of a 707 where a fail-safe load path failed leading to the loss of structural integrity of the horizontal stabilizer. As a result, the regulations regarding fail-safe structure were changed in 1978 through an amendment to FAR 25.571. This amendment (Amdt. 45) introduced certification requirements using damage tolerance concepts. At the time, this was deemed a significant technological advance since directed inspections were introduced to find and repair damage before loss of structural integrity could occur.

When the regulations were changed in 1978, the intent of 25.571 was also changed seemingly obscuring the requirement to design multiple load path, fail-safe structure. The damage tolerance evaluation recommended by AC 25.571 encourages applicants to consider these fail-safe concepts in the design. The two design philosophies, while broadly embracing the concept of allowing the structure to tolerate significant damage, differ significantly in how the capability is proven. Fail-safe methods employ the uses of ultimate strength capabilities of the structure with area out, whereas damage tolerance methods use yield strength or fracture toughness material properties. The damage capability of the structure demonstrated by one method generally does not have any comparison with the damage capability that might be determined using the other method.

While the requirements for initial certification require a damage tolerance evaluation, they normally do not require consideration of pre-existing fatigue damage including MSD and MED. These forms of damage are generally ruled out through the use of fatigue test evidence. The existence of MSD or MED fatigue cracks that might occur later in the service life of the airplane are of a considerable concern because they can affect the damage-tolerance damage sizes that the airplane is capable of sustaining.

### 5.4.1 Fail-Safe Analysis Damage Sizes

The 'fail safe' philosophy of Damage Tolerance used in the original certification relied on a static analysis with certain structural elements failed or partially failed. The 'failed' elements were assumed to carry no loads and the remaining, 'intact' structure was shown to be able to sustain a fail safe load level using a static structural analysis. The analysis assumes that there are no active cracks. The damage size chosen for this analysis was qualitative and was not specified by the regulations. The damage size chosen was large and considered 'conservative' to allow reliance primarily on general visual inspection (i.e. obvious partial failure). This allowed safe operation up to fail safe load levels until the damage was detected and repaired. Damage due to discrete sources, such as rotor burst, is also analyzed in this manner.

### 5.4.2 Damage Tolerance Analysis Damage Sizes

The damage tolerance approach utilizes crack growth analysis from an initial flaw size, to a critical crack length where limit load can just be sustained in the presence of an active crack tip. The requirements for damage tolerance certification are met when the applicant demonstrates that the inspection program developed as a result of the damage tolerance analysis will reliably detect a crack before it reaches the critical crack length.

The damage tolerance damage size is equivalent to the critical crack size. This damage size is highly dependent on a number of things including environment, material, design configuration, and structural loading. In general, applicants have a good deal of latitude in specifying the damage size on a case-by-case basis. Some applicants may not utilize the full residual strength capability of the structure in order to provide some level of conservatism in the inspection programs. In addition to fatigue related inspection programs, the structure is also inspected to detect corrosion and accidental damage

### 5.4.3 Survey of Certification Damage Size

Recently there has been a debate ongoing in the industry about how airplanes were certified to meet the fail-safe and damage tolerance requirements. The debate surrounds the damage sizes the industry used in the certification process. Two actions were taken by the AAWG to clarify this issue.

The AAWG tabulated damage sizes used in the certification analysis submitted by three different manufacturers. Each airplane had a different fail-safe/damage tolerance certification basis. The maximum damage size for each analysis location reported has been tabulated and plotted in order of descending crack size on the following figures:

| | |
|---|---|
| Figure 5.4.3.1 | Pre Amendment 45 (CAR 4b.270 (b)) |
| Figure 5.4.3.2 | FAR 25.571 (c) Post Amendment 45 |
| Figure 5.4.3.3 | FAR 25.571 (b) Post Amendment 54 |

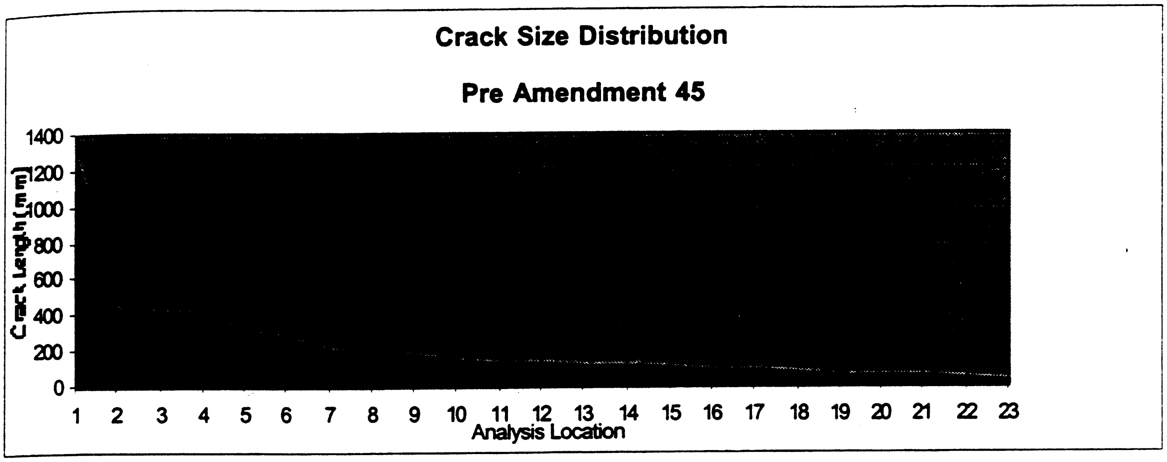



Figure 5.4.3.1 — Crack Sizes Used in Certification, Pre Amendment 45

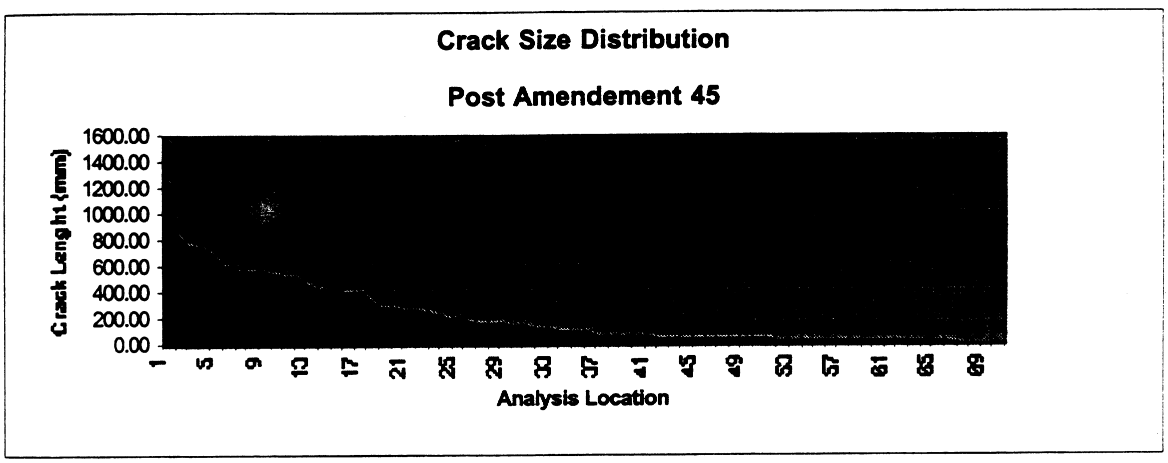



Figure 5.4.3.2 — Crack Sizes Used in Certification, Post Amendment 45

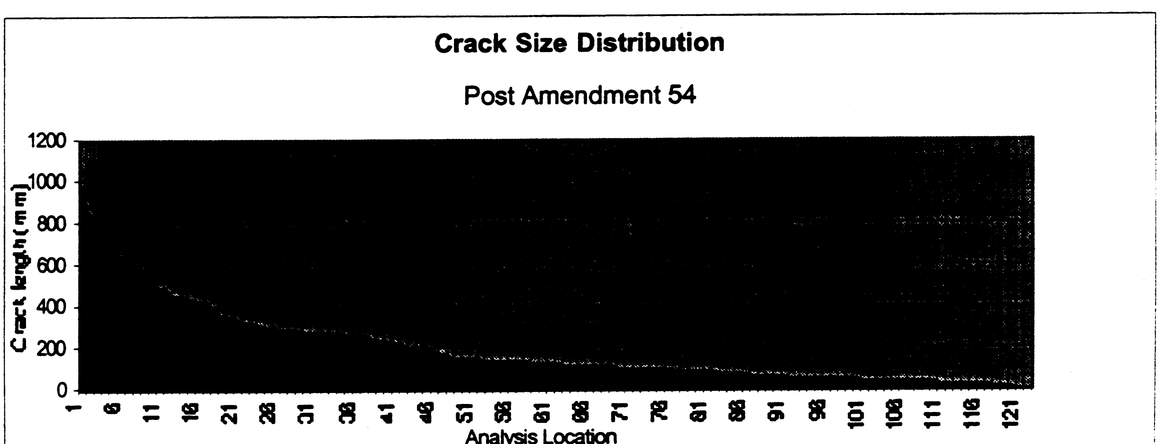



Figure 5.4.3.3 —Crack Sizes Used in Certification, Post Amendment 54

The following observations are drawn from review of these data:

- Charts are representative of industry practice for certification.
- Distributions are similar but independent of certification standards used.
- There is no typical damage size used in certification by the industry or required by the regulators.
- Damage size is highly dependent on location, design detail, and materials used.

### 5.4.4 Safety Enhancements

Airplanes certified prior to FAR 25.571 amendment 45 had supplemental inspection programs (SSIP) mandated by airworthiness directives. The SSIP programs effectively provided similar inspection programs to the inspection programs for airplanes certified post amendment 45. Since 1978, a number of new and innovative programs have been introduced that have enhanced the safety of the fleet for both pre- and post-amendment 45 airplanes. These programs include:

- Mandatory Modification Programs
- Corrosion Prevention and Control Programs
- Repair Assessment Programs
- SSID Revisions for obvious damage

These programs provide an increased level of surveillance. The increased level of surveillance, required by each of these programs at the airplane level, decrease the risk of having undetected structural degradation in high time airplanes with the net result of increasing safety within the fleet. While none of the programs is uniquely aimed at widespread fatigue damage, all have some inherent ability to detect MSD/MED before it becomes WFD.

New certification programs require the development of similar programs as part of the certification process in compliance with FAR 25.1529.

### 5.4.5 Conclusions

Over the past 20 years the regulatory certification requirements have shifted from a static strength fail-safe approach, comparing limit loads with ultimate static allowables, to damage tolerance evaluation comparing limit loads and fracture toughness. The fail-safe philosophy relies upon detection of obvious partial damage by routine inspections, whereas, damage tolerance relies upon directed inspections to detect smaller damage.

Review of the fail-safe/damage tolerance regulations, advisory material and the certification basis for numerous airplane models confirms that a FAA requirement that defines certification damage size does not exist. Certification damage size has always been subject to negotiation between the manufacturer and the regulator.

A common misconception is that all-primary structure has been certified using the classic fail-safe criterion of a two bay skin crack with a failed intermediate member being able to sustain limit load. In many cases this was an obtainable goal for fuselage structure designed by cabin pressure only, but the survey of certification damage sizes in section 5.4.3 shows this criteria was not necessarily applied for structure designed by the combination of flight loads and cabin pressure.

Damage tolerance critical crack criteria comparing limit loads to fracture toughness (active crack tip) should always result in a smaller critical damage size than a fail-safe criterion comparing limit loads and ultimate static allowables. The fact the current damage tolerance damage sizes are similar to prior fail-safe damage sizes is a tribute to the analysis and testing that has been done to increase the residual strength allowables.

There have been proposals within the industry that the original certification basis for an airplane model should be maintained in the presence of MSD/MED. This position with respect to certification damage size is unrealistic for two reasons. First, reanalysis of the structure using the current methods and fracture toughness allowables is likely to result in smaller allowable damage sizes than the old static strength based fail-safe analysis. Second, the presence of MSD/MED in the proximity of the crack tip can reduce the residual strength an additional 5 to 30%.

Whereas the original fail-safe criterion relied upon the detection of obvious partial damage by routine inspections the potential presence of MSD/MED will require directed detail inspections to maintain airworthiness.

## *5.5 MANAGEMENT OF MSD/MED IN THE FLEET*

Since Aloha, known cases of multiple site damage/or multiple element damage have been effectively managed initially through implementation of mandatory inspections analogous to the monitoring periods recommended in Chapter 4.4. The inspection programs were typically implemented by the issuance of airworthiness directives by the regulatory authorities, or by alert service bulletins released by the OEM s. Monitoring periods are considered essential for safety management during the precursor stages (MSD/MED sources) of widespread fatigue damage, until terminating actions have been validated and implemented. Chapter 9.2 presents a detail discussion of the factors influencing lead times, which are necessary for effective long term WFD prevention. Interim safety measures via mandatory inspections are imperative to ensure safety as WFD-prone areas are identified by test, analysis, and/or service history and terminating modifications are accomplished. Monitoring periods should not be considered alternatives to terminating actions, but are deemed to be essential elements of the over-all WFD safety management plan.

## 5.6 SUPPLEMENTAL TYPE CERTIFICATES

### 5.6.1 Background

To understand the scope and magnitude of the supplemental type certificate problem, the AAWG obtained a copy of the *Summary of Federal Aviation Administration Supplemental Type Certificates*, published by the FAA in January 1998. From this list, a database of major alterations to principal structural elements was extracted (Appendix E), and sorted by OEM and airplane model. Broad categories of structural alterations that could affect, alter or nullify recommended OEM widespread fatigue damage audits were then identified.

### 5.6.2 Discussion

The majority of structural STC s with WFD concerns can be grouped into the following categories:

- Passenger-to-freighter conversions (including addition of main deck cargo doors).
- Gross weight increases (increased operating weights, increased zero fuel weights, increased landing weights, and increased maximum take-off weights).
- Installation of additional fuselage cutouts (passenger entry doors, emergency exit doors or crew escape hatches, fuselage access doors, cabin window relocations).
- Complete re-engine and/or pylon modifications.
- Engine hush-kits and nacelle alterations.
- Wing modifications such as the installation of winglets or changes in flight control settings (flap droop), and alteration of wing trailing edge structure.

Many of these STC s also include companion operational mission changes affecting original OEM load/stress spectrums.

Some STC s were found to have changed large areas of fuselage from externally visually inspectable structure to hidden details. Reliance on operator s baseline maintenance program visual inspection requirements may be critical elements of OEM WFD audits, especially during the reliance on monitoring periods to validate analysis or test MSD/MED source predictions. STC s may invalidate these safety management service action assumptions; and would require additional WFD analysis and/or testing. STC s that change baseline maintenance requirements such as frequency of detail visual inspections, or other inspection methods must be evaluated with respect to OEM WFD safety management programs. STC s must be reviewed to account for differences with the OEM baseline maintenance program requirements.

STC alterations creating or affecting principal structural elements must be evaluated to demonstrate the same confidence level as the original OEM structure. This confidence level must be equivalent to that obtained by a two DSG full-scale fatigue test without evidence of MSD/MED occurring in the STC affected structure.

All models identified by AAWG, as candidate WFD assessment fleets had STC changes affecting primary structure, since entering service. A listing of STC s compiled from the January, 1998 edition of the Summary of Federal Aviation Administration Supplemental Type Certificates that could appreciable affect OEM WFD audits of principal structural elements are given in Appendix E. Note: This list contains only modifications accomplished on more than one airplane, single airplane STC alterations are not included.

### 5.6.3 Recommendations

All STC s affecting primary structure should have widespread fatigue damage assessment. The AAWG recommends that the following criteria be used for determination of which STC design characteristics and features would require widespread fatigue damage assessment:

- Major alteration to airplane structure in which a new or modified principal structural element (PSE) is created.

  Example: Freighter conversion with the addition of an outward opening, hoop tension main deck cargo door and door surround structure. The main deck door and door surround structure are new PSEs.

- Major alteration to airplane structure in which the alteration was not certified to damage tolerance requirements.

  Example: Freighter conversion with the addition of an outward opening, hoop tension main deck cargo door with certification prior to application of FAR 25.571, Amendment 45 (pre-1978), or those STC s that have not had structural reassessments to damage tolerance standards (and do not have resulting supplemental structural inspection programs, *with consideration for WFD sources,* implemented).

- Major alteration to airplane structure that appreciably changes the load and stress distribution, load and stress magnitude, load spectra and stress history, stiffness, mission severity, adversely affects inspectability or continued airworthiness limitations of primary structure.

Example: Addition of a winglet to a wing that changes the wing center of pressure, stiffness and spectrum (and may introduce new failure modes).

- Major alteration to airplane structure that contains design features identified by AAWG as susceptible to sources (MSD/MED) of widespread fatigue damage (See Section 5.2).

Example: Freighter conversion adding fuselage plug with main deck cargo door with new skin joints, and hoop tension concentrated load path latch hooks on door surround structure.

#### 5.6.4 Compliance Time for STC WFD Assessment

The compliance time for the widespread fatigue damage assessment on STCs affecting primary structure should be the same calendar compliance as the original structure. The FAA tasking statement for rulemaking and advisory circular activities should state clearly that STCs would be included in the final rulemaking. This statement would alert operators and STC holders of the forthcoming regulatory action, and would strongly recommend that the assessment programs begin (similar to actions already being undertaken by the OEM s for WFD assessment of the type design structure). This notification would give operators and STC holders approximately 3 years to complete the Engineering assessment necessary to meet any final rule requirements, assuming work was begun when the FAA WFD tasking statement was published in the Federal Register. Note: Establishment of design goals for STCs affecting primary structure will be required as part of the rule making activity to follow on from this tasking. Establishment of design goals for STCs will effect both existing and future STC modifications.

#### 5.6.5 Summary

Supplemental type certificate alterations to airframe structure can appreciably affect, alter or nullify widespread fatigue damage programs developed by the OEM. Any comprehensive widespread fatigue damage safety management program must include airframe structure that has been altered by supplemental type certificates. Criteria have been established for determination of categories of STC alterations that must be assessed for widespread fatigue damage. WFD audit requirements for STCs should be the same standard and timelines as original model specific programs. STC alterations creating or affecting principal structural elements must be evaluated to demonstrate the same confidence level as the original OEM structure. This confidence level must be equivalent to that obtained by a two DSG full-scale fatigue test without evidence of MSD/MED occurring in the STC affected structure. Responsibility for completion of WFD audits on STCs will ultimately be the operator s (implemented by FAR 121 and/or 25.1529 rulemaking).

## 5.7 COMBINATION OF MSD/MED SCENARIOS

The AAWG examined the issue of whether or not it was possible to have a simultaneous occurrence of MSD and MED in a single principal structural element. The AAWG concluded that there was a distinct possibility that this could occur on some details that were equally stressed. This scenario should be considered in developing appropriate service actions for a PSE should this event seem likely.

It is suggested that if an area is potentially susceptible to both MSD and MED, then both problems be worked independently. If the thresholds for both MSD and MED indicate a high probability of interaction, then this scenario must be considered.

# 6.0 TECHNOLOGY READINESS

## *6.1 1998 ASSESSMENT OF TECHNOLOGY AVAILABLE*

### 6.1.1 1993 Recommendations

The Industry Committee on Widespread Fatigue Damage (ICWFD) which worked under the umbrella of the AAWG defined research recommendations in their final report issued 1993. The research goals and subjects of interest for the industry for evaluation of Widespread Fatigue Damage were defined and are summarized in the table below.

| **Analysis goals** | **Research subjects** |
|---|---|
| **Initiation of MSD/MED** | |
| Predict realistic cracking scenarios<br>Define a lower limit for MSD/MED initiation | Cracking location<br>Coupon testing for each susceptible area<br>Statistical analysis<br>Guidance material<br>Scatter on material data<br>Redistribution of loads |
| **Propagation of MSD/MED** | |
| Predict cracking development<br>Step towards WFD occurrence limit<br>Monitor MSD/MED | Short cracks: Influencing factors<br>Short cracks: Parametric coupon tests<br>Short cracks: Scatter in material data<br>SIF: Non uniform cracks in complex geometry<br>SIF: Crack interaction<br>SIF: Crack deviation/ bulging/ cold working/ interference<br>SIF: Redistribution of loads<br>Scatter in material data |
| **Residual strength** | |
| Predict residual strength in presence of MSD/MED | RS of ductile materials in the presence of MSD/MED<br>RS validation on large scale components<br>RS: consideration of crack configuration/ curvature/ load transfer<br>RS: consideration of in plane and pressure loadings |
| **Risk analysis** | |
| Predict WFD based on randomisation of WFD<br><br>parameters | Common understanding of basic rules for risk analysis<br>Develop guidance material<br>Specific methods for WFD parameters |
| **Discrete source** | |
| Assess the real concerns with this issue<br>Predict residual strength | Common industry data on discrete source<br>Extend/ location/ type of damage determination<br>Probability analysis (occurrence/ location/ extent) |

### 6.1.2 1998 Status

As a result of worldwide aging airplane activities, research programs were initiated in the United States and in Europe. Programs such as the FAA«s National Aging Aircraft Research Program (NAARP), the European Group for Aeronautical Research and Technology in Europe (GARTEUR) Action Group and the European Brite EuRam Structural Maintenance of Aging Aircraft (SMAAC) Project were established.

The NAARP consists of seven major subjects, one of which deals with Structural Response Modeling and Simulation . Within this project the WFD research activities cover deterministic methodologies as well as probabilistic methodologies. Historically, the FAA research activities in the WFD area have been focussed on residual strength analysis and prediction. Additionally methodologies for crack growth analysis were developed. Furthermore, in 1996 the FAA and NASA jointly funded a contract with an American manufacturer to develop and validate a procedure for the prediction of the point of WFD. This activity included the evaluation and validation of several crack growth and residual strength analysis methods such as equivalent initial flaw size determination, FASTRAN, crack growth criteria T* and Crack Tip Opening Angle (CTOA), Finite Element Alternating Method (FEAM), FRANC2D, FRANC3D/ STAGS. The research work included a large number of coupons, flat panels, stiffened panels, sub-scale cylinders, unstiffened curved panels, stiffened curved panels and aft pressure bulkhead panels sub-scale which were tested regarding fatigue, crack growth and residual strength to support and validate the analytical work. Additionally, probabilistic methodologies can predict the time-dependent probability of the point of WFD, the time dependent distribution of the airplane s residual strength, and the impact of inspections on the structural integrity of the airplane.

An initial collaborative program undertaken by the European aerospace community was started in 1994. This program was supported by the GARTEUR to increase the understanding of MSD in highly loaded joints, and to reduce some of the deficiencies in existing methodologies for predicting the development of MSD in such components. The activities of the project were completed in 1996.

Following the dissolution of the GARTEUR Action Group, financial support for continued collaboration in the field of WFD was secured from the European Commission under the Fourth Framework Program for Research and Technological Development (1994-1998). The GARTEUR activity, and the insights into the problem of MSD, which arose in consequence, were major contributing factors in the success of this proposal. The Brite/ EuRam project (SMAAC) which began in 1996 has the objective of develop engineering tools for the assessment of maintenance actions (inspection and repair) for aging airplanes, and to derive novel design methods to extend the design life of future airplanes with respect to WFD.

The duration of the SMAAC project was originally planned to cover three years, and the project will therefore continue until the beginning of 1999. By the end of the SMAAC project, it is anticipated that a range of theoretical models will have been developed to assess fatigue crack initiation and propagation in aging airplane structures, in order to determine the maintenance actions required to preclude the point of WFD. These models cover the following areas: multiple fatigue crack initiation (probabilistic analysis), multiple fatigue crack growth (deterministic analysis), residual strength in the presence of MSD/MED (deterministic analysis) risk assessment and overall models.

The data base of experimental evidence of MSD/MED has also been increased through an extensive series of fatigue crack growth and residual strength tests, undertaken specifically for the SMAAC project. These test programs are principally intended to provide information to support the development of the analytical models. Therefore they consist of generic specimens, rather than specific airplane components, such as simple specimens (initiation and growth of MSD) and complex specimens (residual strength of representative stiffened panels, i.e. flat stiffened panels with lap or scarf joints, and curved panels with stiffeners, frames and longitudinal lap joints).

Linear elastic fracture mechanics methodologies have been generally adopted in the analytical approaches developed within both the GARTEUR and SMAAC projects, with stress intensity factor solutions obtained through a range of techniques of increasing complexity, such as compounding, stress functions, boundary element analysis and finite element analysis. By the end of the SMAAC project, the analytical models produced by the various partners will have been validated against these experimental results, which should also establish the level of sophistication required to address each of the given problems.

### 6.1.3 Future Research

With respect to the research programs described, the results of the round robin tests, see Section 8.6, and the overview of OEM methodologies, see Sections 8.1 through 8.5, the following research is recommended with the understanding that this research may not affect the first round of audits due in three years:

- Every effort should be made to make data from tests conducted in all research programs available at the earliest possible time before formal reports are issued.
- Extension of the analysis methods to thicker (wing) structure and verification by representative testing.
- Provision of equivalent initial flaw size (EIFS) data for all relevant alloys and fasteners. Fractography after fatigue testing to obtain cracks sizes versus time data, which each OEM could use to substantiate crack growth model and rate data.

- Development of small crack da/dN data for some specific materials and configurations.
- Determination of the scatter in the initiation of MSD/MED for different structural configurations as developed in section 6.1.4.
- Tests currently funded, involving lead crack link-up, should be accomplished as soon as possible to support the first round of audits due in three years.

### 6.1.4 Research Proposal

Several manufacturers use a stochastic approach based on the Monte-Carlo simulation procedure to determine damage scenarios, which are the basis for the WFD evaluation. A series of initial damage scenarios are randomly defined taking material scatter into account.

Generally the material scatter of small coupon specimens is used, i.e. the scatter of cycles to failure of the specimens.

It is recommended the variability of MSD cracking for typical high loaded fuselage joints with high secondary bending be investigated. The investigation consists of constant amplitude tests with small and large coupons and of the comparison with tear down results from real airplane or large curved stiffened panel tests.

The following test program is proposed:

- Constant amplitude tests with small coupons (width one rivet pitch) up to crack initiation, microfractographic investigations to determine the life up to 0.005 and 0.05 crack length.
- Constant amplitude tests with large coupons (width six rivet pitches) up to crack initiation, microfractographic investigations to determine the life up to 0.005 and 0.05 crack length.
- Constant amplitude tests with small coupons (width one rivet pitch) up to failure.
- Constant amplitude tests with large coupons (width six rivet pitches) up to failure.
- Tear down and microfractographic investigation of realistic airplane structure to determine the life up to 0.005 and 0.05 crack length.

The goals of these investigations are to determine the scatter of the fatigue lives up to first 0.005 flaw, first 0.05 flaw and up to failure of the specimens and to compare the results with either data from in-service airplane or representative large panel tests. The joint configuration and the production standard has to be identical for coupons and airplane structural. However, the effect of production changes on the scatter should be investigated additionally.

### 6.1.5 Residual Strength

The presence of MSD adjacent to a lead crack has a significant influence on the residual strength capability of the structure. Former concepts for residual strength evaluation used for type certification considered single damages. These concepts, e.g. Feddersen concept or R-curve approach, are not adequate for the residual strength evaluation in the presence of MSD.

More sophisticated approaches have been developed, e.g. J integral, T* integral, CTOA, elastic-plastic FE analysis, plastic zone link-up. To support these new approaches significant testing with flat and curved panels has been conducted in frame of the US National Aging Aircraft Research Program and the European Brite-EuRam SMAAC (Structural Maintenance of Aging Aircraft) Program. One of the purposes of the test programs is to demonstrate the residual strength capability of airplane structure potentially susceptible to WFD and to verify the concepts, methods and analysis tools for residual strength evaluation.

The U.S. National Aging Aircraft Research program includes testing of flat panels with lap joints, butt joints, and double shear joints to study residual strength affects of MSD. Additional residual strength tests of curved panels with spectrum loading that are representative of typical airplane structure will be conducted with MSD and MED present.

The European research program contains residual strength tests with flat specimens containing open holes, lap joints, double shear joints, butt joints and asymmetric joints for studying different aspects of the residual strength issue in the presence of MSD. Furthermore stiffened flat and curved panels with typical structure were tested under real loading. This structure represents the major fuselage and wing joints of existing small and large European airplanes.

Besides the tests included in the research programs, further residual strength tests are planned by the European and US manufacturers with specific structure of the airplane types to be evaluated regarding WFD. These tests will include major fuselage and wing joints and will validate the WFD analysis for these joints as well as allowing application of the experience to the remaining structure.

## *6.2 1998 AND NEAR FUTURE INDUSTRY NDI CAPABILITIES*

The AAWG reviewed current and future industry NDI capabilities in order to establish a baseline detectable flaw. The ability to detect small flaws in an inspection program is a key element in the decision an OEM must make in determining appropriate service actions. If flaws cannot reasonably be detected, then rework is the only recourse. If the flaws can be detected well before critical length, then a monitoring period approach could be employed to manage the service problem.

### 6.2.1 NDI Round-Robin

In order to determine the readiness of available NDI technology for use in the detection of MSD/MED, the AAWG devised a 'round-robin' survey, consisting of four sample problems on crack detectability in typical structural configurations. These problems were sent to each OEM (Airbus Industrie, Boeing Commercial Airplane Group and Lockheed Martin Aerospace Systems) and the FAA Technical Center for evaluation. In addition, the participants were invited to anticipate the minimum detectable crack size possible after 1 year and 5 years from the time of the survey, given the direction of current research and development in the NDI area. The basic problem statement and accompanying sketches are shown in Figures 6.2.1 and 6.2.2, respectively.

The results of this survey are presented on the following four pages, in which the estimates of crack detectability provided by each participant have been consolidated into a single minimum detectable crack size for each configuration. The detectable crack sizes specified by the OEMs in the survey were generally consistent; in most cases where differences existed, the consolidated results are the largest of the crack sizes provided, with 90/95 probability data used where possible. The information is believed to be conservative; it should be possible to stipulate smaller detectable crack sizes if the exact structural location is specified, rather than the typical scenarios suggested within this survey.

The NDI specialists participating in this survey repeatedly advised caution in the interpretation of the information supplied in response to the AAWG inquiries. The data sheets given on the following pages relate to crack detectability under controlled (laboratory) conditions, without consideration of other variables such as human factors, inspection surface conditions, and operator experience level. Furthermore, the data are based on the optimum NDI method, using 'state-of-the-art' equipment that may not be available to many operators. The simple numerical estimates of crack detectability presented in this section are therefore considered to be useful only as illustrations of typical NDI capability, and should not be used directly in engineering situations without an understanding of the many factors which influence non-destructive inspections.

Nevertheless, the participants appreciated that the information on crack detectability was required by the AAWG in assessing the capability of the industry to ensure the elimination of the potential for WFD from the commercial airplane fleet. The survey provided the AAWG with a useful opportunity to discuss the problem directly with those NDI specialists in the best position to supply those data.

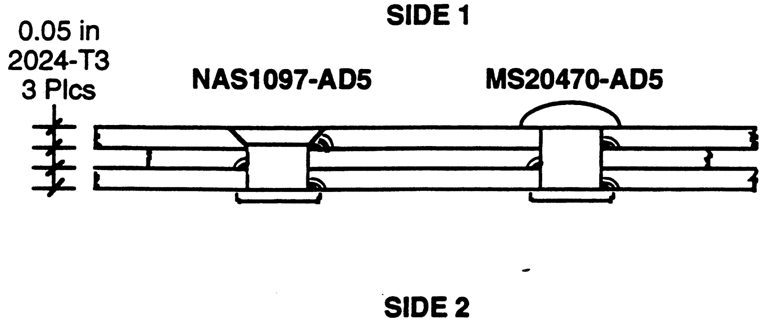
A complete compendium of data from each manufacturer is given in Appendix F.

## NDI Round Robin
## NDI Technology Issues For Discussion

- In your perception what are the NDI Issues associated with the detection of WFD?
  - Multiple Site Damage (MSD)
  - Multiple Element Damage (MED)
- Summarize your major R&D thrusts in NDI that might aid in detection of precursory forms (e.g. MSD and MED) of WFD.
  - IRAD
  - CRAD
- What size of flaws can be reasonable detected in airplane structure (on airplane), with say 90 percent confidence, and 95 percent reliability for the cases illustrated by the figures on the next page?
- What would be the effect on the POD curve for a single detail verses multiple details (e.g. lap splices)?
- In your research initiatives how are the positive (both true and false) NDI findings enunciated and recorded?
- What are the estimated costs Vs detection capability on airplane structure for each of your research initiatives?
- What is the largest crack that can be missed in each of your methods?
- Have the methods you propose been validated on airplane type structure?
- With current research thrusts, what size flaws do you expect to be able to detect in:
  - 1 year?
  - 5 years?

Figure 6.2.1.1 NDI Technology Issues For Discussion

## *AAWG-TPG*
## *ACTION ITEM 4-10*
## *NDI FIGURES*

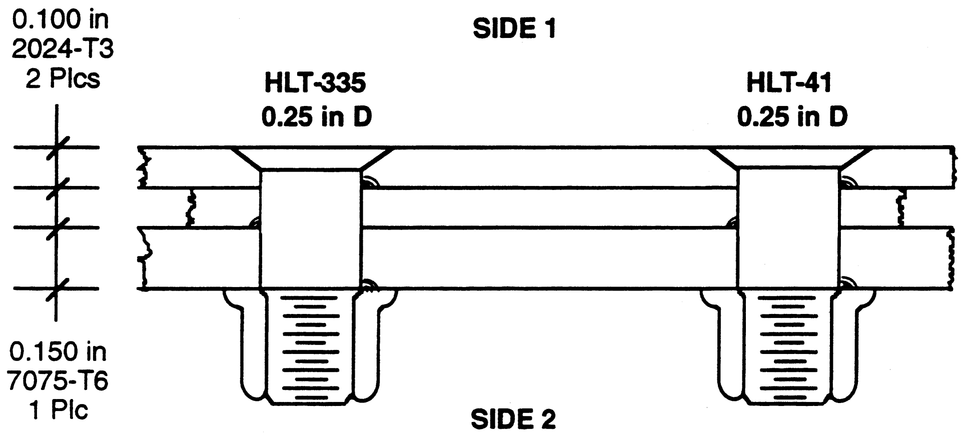



(NO SCALE)

**FIGURE 1. FUSELAGE TYPE STRUCTURE**

**Problem Statement:**

(1) For the six flaw locations shown in Figures 1 and 2, determine the 90,95 flaw size using your best candidate techniques from both SIDE 1 and SIDE 2?
(2) What is the estimated false alarm rate?
(3) What is the largest flaw that could be missed?




(NO SCALE)

**FIGURE 2. WING/EMPENNAGE TYPE STRUCTURE**
Figure 6.2.1.2 NDI Example Problems

## 6.2.2 NDI Round-Robin Results

### 6.2.2 Conclusions

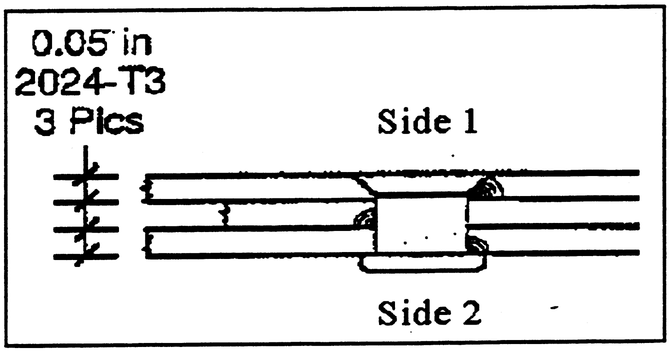
The minimum detectable crack size was not found to have decreased significantly from the limits given at the time of the ICWFD report of 1993, despite the extensive research effort of the past five years. The current 'state-of-the-art' in NDI technology needs significant improvement in both detectability and reliability in the next three years to support audit alternatives for WFD.

The highest potential to achieve the necessary improvements in crack detectability is in the field of semi-automated eddy current systems, incorporating new sensor technologies, multiple frequency application, automated signal pattern evaluation algorithms and documentation features. These advances are expected to result in a significant (20 to 40%) decrease in detectable crack size within the next five years with improved reliability.

## Widespread Fatigue Damage Detectability – Industry Estimate

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 1: Aluminum NAS1097-AD5 flush rivet**




This data represents detectability under controlled (laboratory) conditions, using the optimum NDT method.

Human factors, inspection surface conditions, operator experience level, and other variables have not been considered.

**Side 1:**

| | Industry Estimate | |
|---|---|---|
| | Inches | mm |
| CRACK 1: | **0.05** | **1.3** |
| | *0.04* | *1.0* |
| CRACK 2: | 0.25 | 6.4 |
| | *0.15* | *3.8* |
| CRACK 3: | 0.31 | 7.9 |
| | *0.2* | *5.1* |

Side 2: Dimensions shadowed by upset rivet assumed to be 0.020 (0.5mm)
Rivet upset assumed to be irregular.

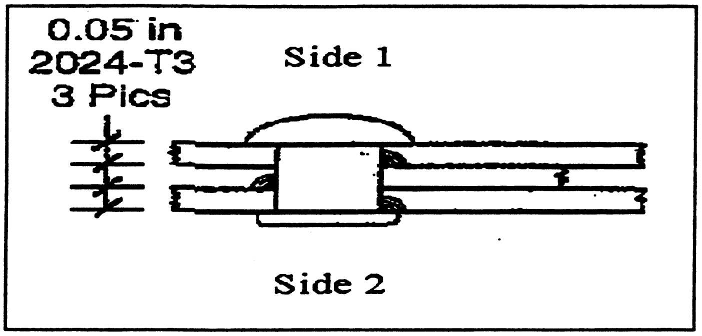
| | Industry Estimate | |
|---|---|---|
| | Inches | mm |
| CRACK 1: | 0.1 | 2.5 |
| | *0.09* | *2.3* |
| CRACK 2: | 0.25 | 6.4 |
| | *0.15* | *3.8* |
| CRACK 3: | 0.31 | 8.0 |
| | *0.25* | *6.4* |

Key: current capabilities in plain text, *five year projections in italics,* **90/95 crack lengths in bold**

# Widespread Fatigue Damage Detectability – Industry Estimate

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 2: Aluminum MS20470 protruding head rivet**




This data represents detectability under controlled (laboratory) conditions, using the optimum NDT method.

Human factors, inspection surface conditions, operator experience level, and other variables have not been considered.

**Side 1:** 0.078" (2.0 mm) = dimension shadowed by MS20470 protruding head

| | Industry Estimate | |
|---|---|---|
| | **Inches** | **mm** |
| CRACK 1: | 0.12 | 3.0 |
| | *0.09* | *2.3* |
| CRACK 2: | 0.25 | 6.4 |
| | *0.2* | *5.1* |
| CRACK 3: | 0.35 | 8.9 |
| | *0.25* | *6.4* |

**Side 2:** Dimension shadowed by upset rivet assumed to be 0.078" (2.0 mm). Rivet upset assumed to be irregular.

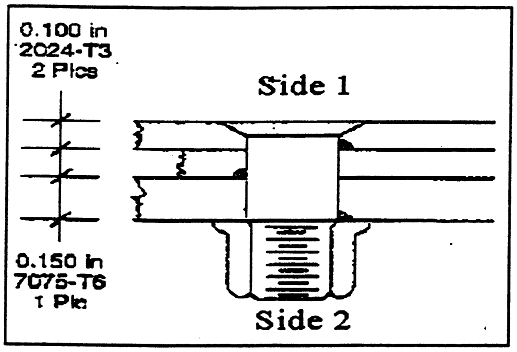
| | Industry Estimate | |
|---|---|---|
| | **Inches** | **mm** |
| CRACK 1: | 0.141 | 3.6 |
| | *0.098* | *2.5* |
| CRACK 2: | 0.25 | 6.4 |
| | *0.2* | *5.1* |
| CRACK 3: | 0.31 | 8.0 |
| | *0.25* | *6.4* |

Key: current capabilities in plain text, *five year projections in italics,* **90/95 crack lengths in bold**

# Widespread Fatigue Damage Detectability – Industry Estimate

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 3: Titanium HLT-335 flush 0.250" (6.3 mm) diameter fastener**




This data represents detectability under controlled (laboratory) conditions, using the optimum NDT method.

Human factors, inspection surface conditions, operator experience level, and other variables have not been considered.

**Side 1:**

| | Industry Estimate | | If fay sealed, with transducer access | |
|---|---|---|---|---|
| | Inches | mm | Inches | mm |
| CRACK 1: | 0.2 | 5.1 | | |
| | *0.15* | *3.8* | | |
| CRACK 2: | 0.4 | 10.2 | 0.31 | 8.0 |
| | *0.35* | *8.9* | | |
| CRACK 3: | 0.79 | 20.0 | | |
| | *0.5* | *12.7* | ***0.1*** | ***2.5*** |

**Side 2:** Dimension shadowed by fastener collar assumed to be 0.125" (3.2 mm). No sealant cap present.

| | Industry Estimate | | If fay sealed, with transducer access | |
|---|---|---|---|---|
| | Inches | mm | Inches | mm |
| CRACK 1: | 0.15 | 3.8 | | |
| | *0.13* | *3.3* | | |
| CRACK 2: | 0.425 | 10.8 | 0.39 | 10.0 |
| | *0.375* | *9.5* | | |
| CRACK 3: | 0.675 | 17.1 | | |
| | *0.625* | *15.9* | | |

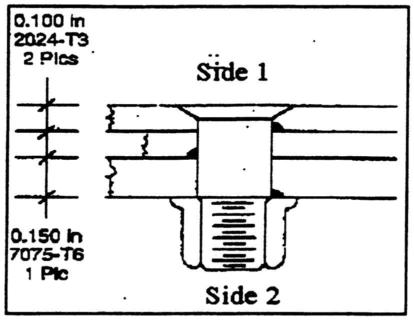
NOTE: Inspection for crack 3 from side 2 is a very unlikely inspection scenario.

Key: current capabilities in plain text, *five year projections in italics*, **90/95 crack lengths in bold**

# Widespread Fatigue Damage Detectability – Industry Estimate

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 4: Steel HLT-41 flush 0.250" (6.3 mm) diameter fastener**




This data represents detectability under contrc (laboratory) conditions, u the optimum NDT metho

Human factors, inspectio surface conditions, operε experience level, and oth variables have not been considered.

**Side 1:**

| | Industry Estimate | | If fay sealed, with transducer access | |
|---|---|---|---|---|
| | Inches | mm | Inches | mm |
| CRACK 1: | 0.1 | 2.5 | | |
| | *0.1* | *2.5* | | |
| CRACK 2: | 0.3 | 7.6 | 0.31 | 8.0 |
| | *0.2* | *5.1* | | |
| CRACK 3: | 0.55 | 14.0 | | |
| | *0.35* | *8.9* | ***0.1*** | ***2.5*** |

**Side 2:** Dimension shadowed by fastener collar assumed to be 0.125" (3.2 mm). No sealant cap present.

| | Industry Estimate | | If fay sealed, with transducer access | |
|---|---|---|---|---|
| | Inches | mm | Inches | mm |
| CRACK 1: | 0.125 | 3.2 | | |
| | *0.1* | *2.5* | | |
| CRACK 2: | 0.425 | 10.8 | 0.39 | 10.0 |
| | *0.375* | *9.5* | | |
| CRACK 3: | 0.675 | 17.1 | | |
| | *0.625* | *15.9* | | |

NOTE: Inspection for crack 3 from side 2 is a very unlikely inspection scenario.

Key: current capabilities in plain text, *five year projections in italics,* **90/95 crack lengths in bold**

## 6.3 NDI Improvements with Regard to the Challenge of MSD

Residual strength reductions due to multiple site damage scenarios require appropriate measures in order to maintain the structural integrity over the period of planned flight cycles. Among other measures, improved and advanced NDI technologies is a candidate with a promising potential for the detection of MSD. Significant improvements in comparison with the currently available NDI technologies are expected from using the following technologies and computer software algorithms:

- Semi-automatic crack detection systems (manually operated probe systems with fully automated signal pattern evaluation)
- Improved multiple frequency eddy current systems
- SQUID sensor technology

All of the technologies mentioned above already exist today and have entered into advanced field trials. Further information on each of these technologies is given below. In order to fulfill the requirements for detection systems capable of reliably resolving the cracks associated with MSD, the improved NDI technologies must provide:

- A significant improvement in resolution capacity (20 to 40% over today s capability)
- Low false call rates (<1%)
- A reduction of the human factors element
- Semi-automatic signal pattern evaluation

Although new NDI technologies will certainly improve the detectability of fatigue cracks hidden in the second and third layer of structure, the highest potential for achieving the required improvements is seen in the field of semi-automated NDI systems incorporating new sensor technologies, multiple frequency eddy current applications, automated signal pattern evaluation algorithms and documentation features. Engineers involved in the NDI development process should interact with other disciplines that rely on their technology in order to establish requirements for detectability and reliability in the qualifications of new NDI technology. Such requirements, for future research, should be structured around the five most critical locations potentially susceptible to MSD for each OEM. The requirement should contain details about the manufacturing of the structure, expected flaw locations and direction of initiation and the expected crack shape over time.

The necessary improvements can be achieved within two to four years, provided that the activities of both American and European research institutes, academia, and OEMs are coordinated and financed by the organizations involved in aging airplane development activities.

1. Semi Automated Crack Detection Systems

This system is based on eddy current and/or ultrasonic techniques. Semi automated systems are a combination of manually operated probes and fully automated measuring devices with software based on-line evaluation and classification of signal patterns. The fully automated measuring and evaluation algorithms of these crack detection systems eliminate the element of human factors to a high degree, thus making the inspection results much more reliable in comparison to current techniques. With the existing systems available in America and Europe combined with necessary improvements with regard to small crack detectability, semi automatic systems will become a major element in NDI applications for MSD detection purposes.

2. Improved Multiple Frequency Eddy Current Systems

Specialized vendors have offered various types of equipment for both rotating and sliding probe systems that make use of multiple frequency eddy current.

Use of these systems during teardown inspections and coupon tests have clearly demonstrated the advantages of multiple frequency systems with regards to:

- The identification of cracks
- The distinction between cracks, corrosion, permeability and geometry effects
- The determination of defect depth and size in hidden layers with an acceptable range of error.

As the existing systems have already demonstrated clear advantages in comparison with conventional ones, the development potential for multiple frequency eddy current applications should be thoroughly examined and exploited for MSD detection purposes.

3. SQUID Sensor Technology

SQUID technology (Super-conducting Quantum Interference Device) uses an extremely sensitive measuring element for the detection of magnetic field variations in combination with eddy current application.

This technology, driven by the academics, equipment manufacturers and OEMs in Europe, is offering a promising potential for improvements in fatigue crack detectability, particularly in hidden positions of lap splices and thicker multiple structural elements.

Due to the latest achievements in minimizing the dimensions of the cryostat device, the equipment has become portable so that it can be used under normal in-service maintenance conditions. Comparisons of PODs as achieved with the SQUID technique versus conventional equipment are showing equivalence on the tested structures but the SQUID technology is not yet considered to have reached the limits of its capabilities.

# 7.0 AIRPLANE SPECIFIC EVIDENCE OF MSD/MED

## *7.1 HEALTH OF FLEET WITH REGARD TO WIDESPREAD FATIGUE DAMAGE SOURCES*

It can be easily demonstrated that a significant effort is being made in the industry to assess, inspect, and modify airplane structure to maintain the highest level of safety. Most of the individual activities, which are part of the larger effort, can trace at least part of their origins to an early report and resolution of a discrete problem by an operator/manufacturer team. While not geared specifically to identification of potential WFD issues, the current system of operator/manufacturer communications has in retrospect been quite useful in identification and resolution of a number of issues which can today be classified as WFD concerns. A discussion of some examples will be covered in section 7.3.

### 7.1.1 Background -- The Communication Process Today.

The basic processes currently used to facilitate these operator/manufacturer communications have changed little over the years, although technology has improved the speed of communication. Also, an increasing awareness of the potential long-term effects of structural repairs has caused a corresponding increase in the number of issues presented to the manufacturer.

In order for the manufacturer to conduct the necessary analyses on individual airplanes and begin or continue an assessment of fleet impact, several key data elements are documented:

- Operator
- Aircraft Line No.
- Hours/Cycles
- When/How discovered
- Damage Description; location, geometry, size, related factors such as adjacent damage, prior occurrences, mitigating factors
- Sketches/photos may be submitted
- A proposed repair may also be suggested

The manufacturer catalogs the information and generates the necessary data to substantiate a disposition of the condition:

- Repair design
- Special conditions/processes such as cold working, specific shoring requirements, etc.

- Follow-up inspections, if required
- OEM analysis and assessment of failed component(s).

The manufacturer may initiate additional communications with other operators to solicit feedback on possible related occurrences. These related occurrences may not have been previously reported for a variety of reasons, such as operator decision to replace versus repair, or damage was detected and corrected at an earlier stage with existing data.

The manufacturer combines this feedback with earlier reports, and assesses the issue for possible further action. Dialog with operators is maintained through a variety of methods including manufacturer representatives, Telex, operator letters, and contact through groups like the STGs. All are valid means for information collection and dissemination.

The existing communication process has been demonstrably effective in identifying MSD/MED, but there is room to improve

### 7.1.2 Additional Operator Actions

The operator should make every effort to provide the following information to the OEM or STC holder to help identify and resolve potential MSD/MED issues sooner:

All Cases

- An exact description of the damage, including crack length, location, flight cycles/hours, and condition of structure.
- Diagram of crack orientation.
- Crack specimen from service airplane (damaged structure may be needed for detailed examination), when requested
- Results of follow-up inspections by operator that identify similar problems on other airplanes in the fleet

MSD

- Re-occurring findings of similar problem in fleet
- Findings where inspections accomplished during the initial repair identify additional damage sites
- Adjacent repairs with similar types of damage

MED

- Operator inspection finds damage at multiple locations

### 7.1.3 Additional OEM Actions

The OEMs will also need to add or improve capabilities in the identification process. Some example areas:

- Review service history files for possible fleet data to find or verify trends
- If only limited fleet data is available, it may be necessary to support with additional near-term analysis to predict or confirm occurrence as an MSD/MED issue (as opposed to incidental or random damage)
- Verify that similar adjacent details are in fact similar in detail and operating at similar stress levels before classifying a single event or single location as MSD or MED.
- Educate OEM Support personnel to potential MSD/MED scenarios.

### 7.1.4 OEM/Operator Improved Communication Improvements

Operators and OEMs need to institutionalize a more robust communications model to provide the greater detail described above, and ensure potential issues are recognized sooner. In addition to the external communications between the parties, internal processes and communications models will need to be improved. In particular;

- Operators must work to report all findings, not just report the first few findings and then stop reporting additional findings because they are an old subject
- Diligence will be required on the part of the operators to assure that a developing MED problem is not masked by parts replacement at repetitive maintenance visits
- OEMs also need to look at other ways to uncover potential MSD/MED issues, such as spares demand for susceptible details
- Steps need to be taken to raise awareness at operators in maintenance organizations in addition to the few engineering groups involved

### 7.1.5 Role of the STG

The STGs have proven to be a key resource in the overall effort to improve the structural health and safety of the transport fleet. The STGs can play an ongoing, constructive part in the management of MSD/MED issues. Operator STG members should participate in OEM planning, and assist in the OEM evaluation and management of potential MSD/MED susceptible structure. Some specific suggestions include:

- For all models exceeding 75% DSG the OEM will develop and maintain a current listing of MSD/MED susceptible locations. This listing will be reviewed by the STG and made available to all operators of that model by the OEM customer support organization.
- When appropriate, the STG will recommend that a formal MSD/MED susceptible area inspection program be initiated focusing on the active high time airplanes (over 75% DSG) from each of the models included in tasking. Operators of these airplanes would be requested to provide Fractography specimens from each of the susceptible areas at the next D-Check. OEMs would provide preplanned repairs and/or replacement parts as applicable. Samples would provide flaw or crack distribution data.
- Add notes in SRM and operator-developed standard repairs for maintenance staff to notify Engineering with details of repairs.

## *7.2 VALUE OF SERVICE DIFFICULTY REPORTS*

### 7.2.1 Evaluation Process

The existing FAA Service Difficulty Reporting database, collected per FAR 121.703, was researched and evaluated by AAWG OEMs and an operator (Delta). The process consisted of down-loading the database from the FAA s website, application of key word query programs keyed to a date range from January 1, 1996 to May 1, 1998, all fuselage entries, and all operator reports for B727, 737, 747, L1011 and DC-9 airplane models. The key word search consisted of identification of all cracked structure in fuselage skins, pressure bulkheads and stringers and/or longerons, as applicable.

### 7.2.2 Results and Conclusions

Ten percent of fuselage skin crack reports on one model airplane indicated MSD in individual skin panels. None of the individual reports indicated MED cracks in fuselage frames or pressure bulkheads.

The conclusions of the AAWG concerning the effectiveness of SDR data for evaluating the health of the fleet with respect to widespread fatigue damage can be summarized as follows:

- The quality of discrepancies reported on the SDRs required considerable model-specific expertise to understand and analyze the reports
- The report format is not conducive to automated analysis
- SDRs are not timely, often lagging other more direct methods (full scale fatigue tests, operator/OEM repair coordination, AAWG Structures Task Group

meetings, etc.) routinely used to identify susceptible areas by significant periods of time.

- The data was not representative of the world-wide fleet

- Cracks reported individually did not make any multiple events apparent without prior knowledge of the reviewer

- There were no new MSD/MED findings, i.e. not already identified by the OEM without service actions already in place

- Some usefulness in providing an indication of frequency of occurrence

Based on this activity, AAWG has concluded that further or ongoing review of SDR data is not a necessary or beneficial process in the identification or resolution of WFD related service problems. Furthermore, much difficulty was experienced in establishing trends from the data.

## *7.3 AIRPLANE SPECIFIC EVIDENCE OF MSD/MED*

### 7.3.1 Evaluation Process

AAWG members conducted a review of fatigue test and service data to determine the health of the fleet with respect to widespread fatigue damage.

The data collected and summarized consisted of identification of design detail, source of the data, type of problem (MSD/MED) encountered, number of airplanes affected, service action status, service action threshold, and regulatory status.

### 7.3.2 Results and Conclusions

Limited MSD/MED test or service findings were identified on each model surveyed. (B727, 737, 747, L1011, A300, A310, DC-9, BAe1-11) Susceptible structure consisted of fuselage longitudinal and crown circumferential skin joints, fuselage stringer splices, pressure bulkheads, (rings / web splice and attach angle) shear ties, skin at stringer run-outs, skins and beams, frames in flat fuselage areas, doorskin flat pressure bulkheads, fuselage frames adjacent to doorways, horizontal stabilizer stringer subject to acoustic excitation, window band areas, frames below cargo door cutouts, and wing chordwise splices, cargo door latch spool attachments, wing box drain holes wheel well pressure panel beams.

All A-300 and A-310 MSD/MED problems were identified by test. The remaining fleets were primarily, but not exclusively, identified by service reports.

Service actions have been issued for every finding each service action resulted in the issuance of airworthiness directives to mandate inspections in each case.

## 7.3.3 Airplane Specific Instances Of MED / MSD

Table 7.3.3.1 Specific Evidence of MSD/MED In-Service or Test

| SECTION 5.2 FIGURE No. | DESIGN DETAIL DESCRIPTION | SOURCE OF DATA SERVICE / TEST | MSD OR MED |
|---|---|---|---|
| 1 | FUSELAGE LONGITUDINAL LAP JOINT | T | MSD |
| 1 | FUSELAGE LONGITUDINAL BUTT JOINT | T | MSD |
| 1 | FUSELAGE LONGITUDINAL LAP JOINTS | S | MSD |
| 1 | FUSELAGE UPPER ROW LAPSPLICE | S | MSD |
| 1 | FUSELAGE UPPER ROW LAPSPLICE | S/T | MSD |
| 1 | FUSELAGE LOWER ROW LAP SPLICE | S/T | MSD |
| 1 | FUSELAGE LOWER ROW LAP SPLICE | S | MSD |
| 1 | FUSELAGE LONGITUDINAL SKIN LAPS AND TEAR STRAPS | S/T | MSD |
| 1 | FUSELAGE WINDOW BELT LAP SPLICE | S | MSD |
| 2 | FUSELAGE STRINGER COUPLING | T | MED |
| 2 | FUSELAGE CIRCUMFERENTIAL JOINT | T | MSD |
| 2 | FUSELAGE CIRCUMFERENTIAL JOINT | S | MSD |
| 2 | FUSELAGE CIRCUMFERENTIAL JOINT | S | MSD |
| 2 | FUSELAGE CIRCUMFERENTIAL JOINT | S | MSD |
| 2 | AFT PRESSURE BULKHEAD CROWN STRINGER FITTING | S | MED |
| 3 | FUSELAGE MILLED RADIUS | T | MSD |
| 4 | FRAME FEET (CENTER FUSELAGE) | S | MED |
| 4 | FUSE FRAMES CRACKING ADJACENT TO FWD PASSENGER DOORWAY | S | MED |
| 4 | FUSELAGE SECT 46 FRAMES | S | MED |
| 4 | SECT 43 FRAMES BELOW MAIN DECK CARGO DOOR | S | MED |
| 4 | FRAMES BELOW MAIN DECK CARGO DOOR | S | MED |
| 4 | FUSELAGE LOWER LOBE FRAMES | S | MED |
| 4 | FUSELAGE FRAMES AND FLOOR BEAMS IN FLAT SIDED AREAS | T | MED |
| 4 | FUSELAGE AFT UPPER FRAMES | T | MED |
| 4 | FUSELAGE AFT LOWER FRAMES | T | MED |
| 4 | FRAMES ABOVE PASSENGER WINDOW | S | MED |
| 5 | FUSELAGE STRINGER TO FRAME ATTACH | S | MED |
| 6 | FUSELAGE SHEAR CLIP END FASTENERS ON SHEAR TIED FRAMES | S | MED |

Table 7.3.3.1 Specific Evidence of MSD/MED In-Service or Test Continued

| SECTION 5.2 FIGURE No. | DESIGN DETAIL DESCRIPTION | SOURCE OF DATA SERVICE / TEST | MSD OR MED |
|---|---|---|---|
| 7 | REAR PRESSURE BULKHEAD | T | MSD |
| 7 | REAR PRESSURE BULKHEAD ATTACH ANGLES | T | MSD |
| 7 | REAR PRESSURE BULKHEAD ATTACH ANGLES | T | MSD |
| 7 | AFT PRESSURE DOME OUTER RING AND DOME WEB SPLICES | S | MSD |
| 7 | AFT PRESSURE BULKHEAD WEB SPLICE | S | MSD |
| 7 | AFT PRESSURE BULKHEAD TEE | S | MSD |
| 7 | AFT PRESSURE BULKHEAD CROWN STRINGER FITTING | S | MED |
| 8 | CIRCUMFERENTIAL SKIN JOINT AT AFT PRESSURE BULKHEAD | S | MSD |
| 9 | FUSELAGE CENTER SECTION SHEAR PLATES | T | MED |
| 9 | FUSELAGE CENTER SECTION SHEAR WEB | S | MSD |
| 9 | FUSELAGE GANTRIES | S/T | MSD |
| 10 | FUSELAGE WINDOW BELT | S | MSD |
| 11 | OVERWING FUSELAGE ATTACH | S | MED |
| 11 | FUSELAGE OVERWING FRAMES AT FLOOR | S | MED |
| 12 | UPPER CARGO DOOR LATCH SPOOL BOLTS | S | MED |
| 13 | FUSELAGE DOUBLER RUNOUT BELOW AIRSTAIR DOOR CUTOUT | S | MSD |
| 14 | WING TOP SKIN AND STRINGER JOINT AT RIB | S/T | MSD |
| 14 | WING-CHORDWISE SPLICES (S.O.B. SPLICE PLATE) | S | MSD |
| 14 | WING LOWER PANEL JUNCTION FITTING | T | MSD |
| 15 | WING LEADING EDGE RIB | S | MSD |
| 16 | WING BOTTOM SKIN STRINGER RUN-OUTS ADJACENT TO RIB | S/T | MED |
| 16 | CRACKS IN SPANWISE STRINGERS OF HORIZONTAL STABILIZER | S | MED |
| 16 | CENTER WING BOX CROSSING AREAS | T | MED |
| 16 | CENTER WING BOX DRAIN HOLES | T | MED |

# 8.0 OVERVIEW OF OEM METHODOLOGIES

## 8.1 AIRBUS INDUSTRIE

### 8.1.1 Probabilistic Assessment of Structure Susceptible to MSD/MED

A fatigue endurance test of a structure containing a row of nominally identical fastener holes is analogous to testing a series of simple coupons with a single fastener hole. Each single hole coupon initiates detectable cracking at different times, despite being manufactured to a common procedure; similarly, multiple hole structures will not initiate detectable cracks at the same time at each hole.

It is assumed that the crack initiation time at each site susceptible to fatigue cracking is connected to the probability distribution for fatigue endurance given by testing a large number of single hole coupons. A good estimate of the scatter (*i.e.* the standard deviation) in the fatigue endurance of details representative of the airplane structural feature is therefore fundamental to the MSD/MED assessment. The degree of variability in the manufacturing process originally used in the production of the component determines whether MSD or MED will occur, since poor quality control in manufacture results in isolated rogue flaws and the 'lead crack' scenario of traditional damage tolerance criteria. It may be extremely difficult to establish the appropriate level of scatter for a structural evaluation in an ageing airplane. Unfortunately, a supplemental fatigue endurance test programme may not furnish the required information, since 'new build' test coupons are unlikely to be representative of the original production standard, due to process and material changes over the service life of the airplane. Consequently, the conservative assumption of low scatter in fatigue endurance may have to be adopted in order to induce MSD/MED scenarios within the analysis. The assumption of high scatter suppresses multiple cracking scenarios and encourages isolated lead crack scenarios, and may result in a shorter overall fatigue endurance for a multiple hole structure.

The magnitude of the scatter directly affects the mean of the important outputs from a typical MSD fatigue assessment, *viz.* the period to first detectable crack, the period from detectable cracking to a critical crack scenario, and the overall fatigue endurance of the multiple hole structure. However, where there is any uncertainty in the scatter, a fixed standard deviation based upon the largest known values will always give a conservative analysis of fatigue endurance, although the simulation may not include many MSD/MED scenarios.

### 8.1.2 Calculation Procedure

- Each potential damage site in the structure (generally two per fastener hole) is allocated a different fatigue endurance, drawn randomly from the overall distribution (lognormal or Weibull) of fatigue lives for the simple coupons.

- The crack growth period is divided into intervals within a time-stepping routine, with the following calculation at each discrete time-step:
  - each damage site is checked for the initiation (or otherwise) of a fatigue crack;
  - the growth of each initiated fatigue crack is estimated through the techniques of linear elastic fracture mechanics; the stress intensity factor solutions account for the interaction of adjacent cracks and fastener holes in a simple compounding process, or through detailed finite element analysis;
  - the link-up of adjacent cracks is included within the crack growth calculation, according to the criterion of touching' crack tip plastic zones.

- The calculation stops at some pre-defined condition, *viz.* growth to a given lead crack size or structural failure according to a residual strength criterion such as the conventional crack resistance curve, or *R-curve*', techniques, with an allowance for crack interaction.

These stages form a single 'Monte Carlo' iteration; the calculation is now repeated many times, but with a different fatigue endurance (randomly allocated) at each potential damage site, such that each individual calculation represents a different damage scenario. The final output is a failure distribution (overall fatigue endurance or residual strength) associated with the multiple hole configuration. The results are generally presented graphically; for example, the overall fatigue endurance for the multiple hole configurations can be plotted against the period to the first detectable crack, as in Figure 8.1.1.

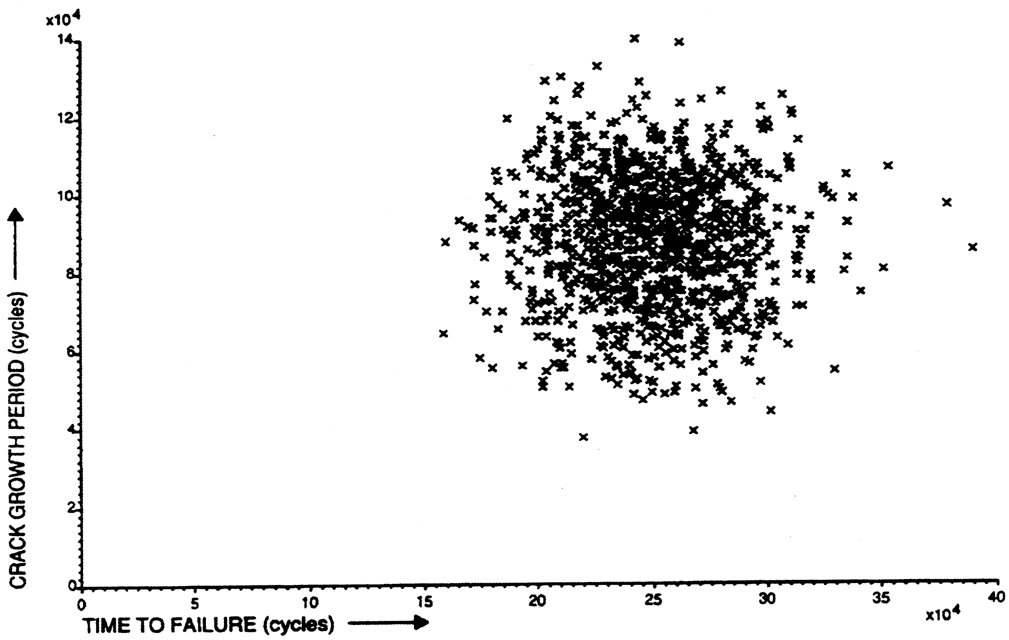



Figure 8.1.1 Fatigue endurance of multiple hole configurations.

The results can also be presented statistically by replacing the individual data points by confidence limits. The reliability of this probabilistic assessment depends on the number of scenarios considered; for example, an accuracy of 1 in 10000 requires the evaluation of at least 10000 scenarios. Figure 8.1.2 shows confidence limits on fatigue endurance for the same multiple hole configuration as in the previous illustration, along with the results of six nominally identical fatigue tests of a representative multiple hole coupon. Although the scatter in the experimental results is high, the data may be seen to be well bounded by the 99% confidence interval.

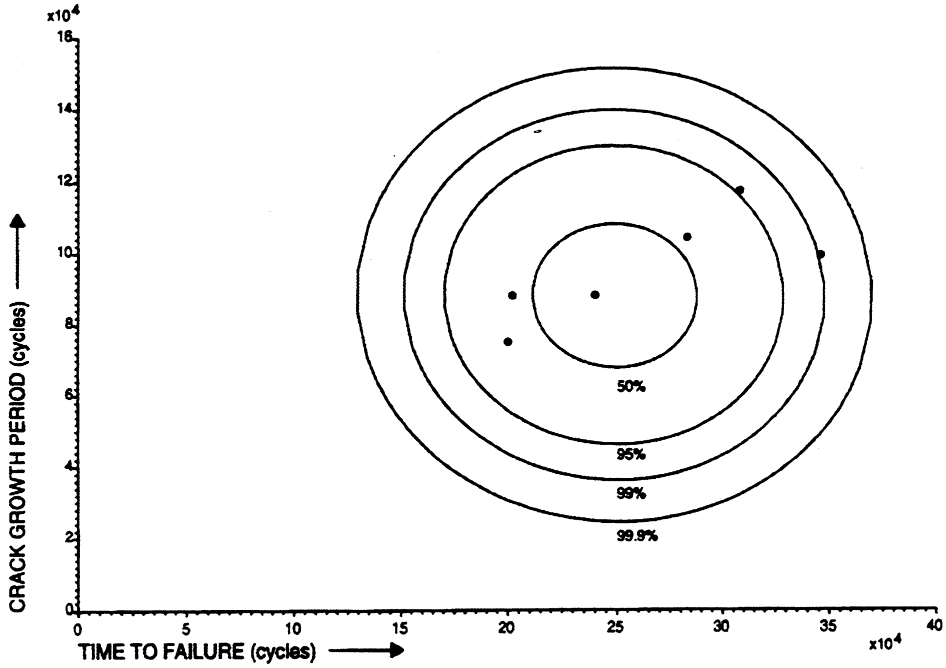



Figure 8.1.2 Confidence limits for multiple hole configurations.

## 8.1.3 Monitoring Period

In general, the most severe cases of adjacent multiple cracks are likely to develop only after a very long period of fatigue cycling. The most probable scenarios at earlier fatigue lives will be those associated with isolated cracks, for which a damage tolerant inspection and repair strategy should still be possible. However, the increased probability of multiple cracking in an aging airframe should be reflected within the airplane maintenance program, through the introduction of additional directed inspections providing an increased level of surveillance.

If the mean time of occurrence of failure due to WFD is established, either by calculation or test evidence, then a *'Point of WFD'* may be derived (possibly by applying a factor to the mean time for WFD) which represents a lower bound to the mean. Consequently, a *'Monitoring Period'* for operation within the MSD/MED regime may be defined, with the intention of avoiding periods where a damage tolerant inspection strategy may be inadequate because of extensive fatigue cracking. Additional inspections within the Monitoring Period are therefore initiated at some MSD/MED threshold, and continue until the Point of WFD, at which time the airframe must be modified or retired. The repeat inspection interval within the Monitoring Period will clearly be significantly shorter than for normal damage tolerance inspection programmes, in view of the increased risk of structural failure.

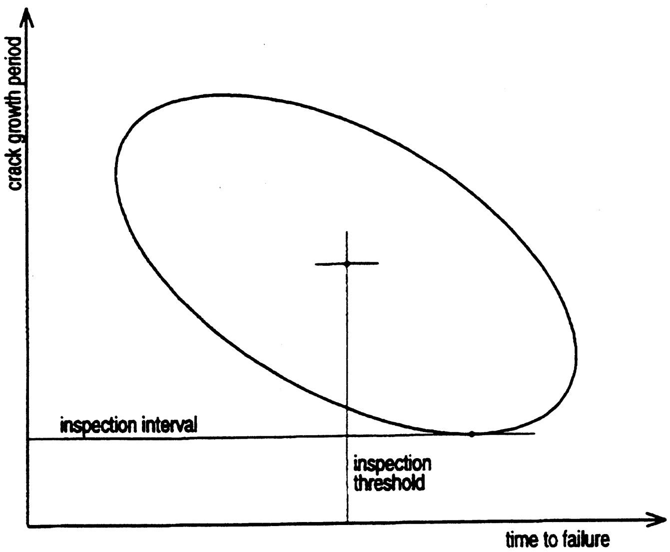



Figure 8.1.3 Inspection threshold & interval from confidence limit.

The basic parameters defining the Monitoring Period — the MSD/MED threshold, the Point of WFD, and the repeat inspection interval — may all be deduced from the results of a probabilistic assessment of structure susceptible to MSD/MED. In Figure 8.1.3, a typical confidence limit from such a calculation is shown, along with the mean time to failure from all of the different scenarios considered. The MSD/MED threshold and the Point of WFD may be established by applying appropriate factors to the mean failure period, whilst the repeat inspection interval is derived from a confidence limit on the crack growth period. A less conservative inspection interval calculation is illustrated in Figure 8.1.4, whereby the interval reduces with increasing airplane life, as a result of the reduced crack growth period in a multiple crack scenario. However, such a variable inspection programme would have to be coincident with airline maintenance schedules.

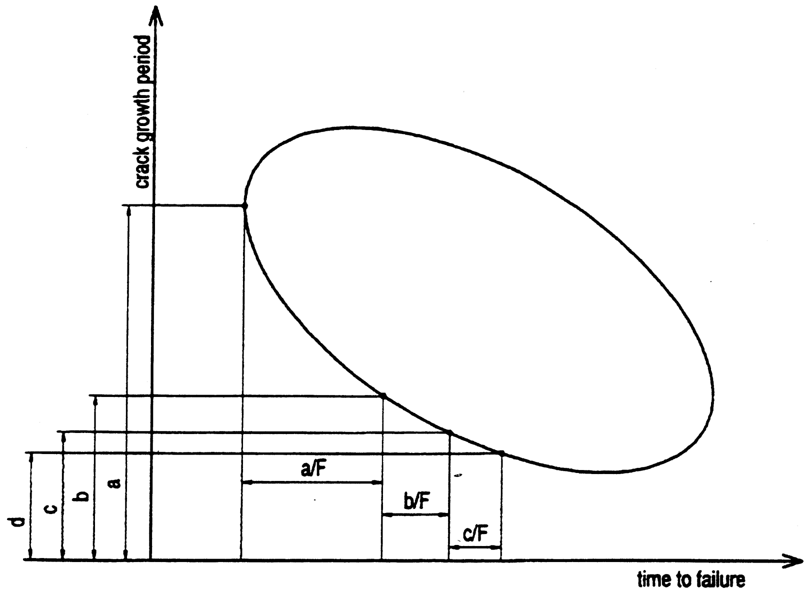



Figure 8.1.4 Modification to inspection interval.

## *8.2 BOEING COMMERCIAL AIRPLANES*

### 8.2.1 Initiation / Threshold Determination

BCA currently treats MSD/MED initiation the same as MSD/MED detectable. The aim is to achieve an efficient and economical inspection program by starting it when cracks become detectable for a specified inspection method. A MSD/MED initiation with high reliability level is also achieved by focusing on very early cracking in a whole fleet. This reliability is quantifiable because the variabilities of life to cracking at different tiers of aircraft structures have been characterized by extensive testing and decades of operational fleet data. BCA uses the two-parameter Weibull probability distribution, one of the extreme value distributions,

$$F(x) = 1 - \exp\left[-\left(\frac{x}{\beta}\right)^{\alpha}\right];$$

$F(x)$ = Weibull cumulative probability function
$x$ = fatigue life in flights
$\alpha$ = shape or scatter parameter
$\beta$ = scale parameter or characteristic fatigue life

to model the variabilities at all different structural tiers. In general, BCA considers three structural tiers in WFD analysis, namely, critical detail, WFD component, and airplane. A critical detail, e.g., one or more adjacent rivets where early cracks will occur, is the building block of MSD/MED in a component. A WFD component, e.g., a lap splice, is an assembly of critical details. An airplane usually contains a number of underlying WFD components.

If $\alpha_1$ and $\beta_1$ are the statistics of crack initiation life for critical details in a WFD component, the characteristic life $\beta_2$ of WFD component to have $r_1$% of critical details cracked can be estimated by, letting $x \approx \beta_2$ in the above Weibull distribution,

$$\beta_2 \approx \beta_1 \times \left[-\ln(1 - r_1\%)\right]^{-1/\alpha_1}$$

Similarly, given $\alpha_2$ and $\beta_2$ the statistics of life to damage for same WFD components in an airplane, the characteristic life $\beta_3$ of airplane to have $r_2$% of these WFD components damaged (in $r_1$% of critical details) can be estimated by

$$\beta_3 \approx \beta_2 \times \left[-\ln(1 - r_2\%)\right]^{-1/\alpha_2}$$

BCA defines the MSD/MED initiation as an very early cracking event, say $r_3$% of airplanes in a fleet to have $r_2$% of WFD components damaged in $r_1$% of critical details, where $r_1$ usually is around 10 and $r_2$ & $r_3$ usually around 1. Thus, the MSD/MED initiation is estimated by the characteristic life $\beta_4$ of a fleet to have $r_3$% of airplanes with the prescribed damage. Let $\alpha_3$ and $\beta_3$ be the statistics of life of airplane in a fleet to the prescribed damage.

MSD/MED Initiation:

$$\begin{aligned}
\beta_4 &\approx \beta_3 \times \left[-\ln(1 - r_3\%)\right]^{-1/\alpha_3} \\
&\approx \beta_1 \times \left[-\ln(1 - r_1\%)\right]^{-1/\alpha_1} \times \left[-\ln(1 - r_2\%)\right]^{-1/\alpha_2} \times \left[-\ln(1 - r_3\%)\right]^{-1/\alpha_3} \\
&\approx \beta_1 \div \prod_{i=1}^{3} \left[-\ln(1 - r_i\%)\right]^{1/\alpha_i} \\
&\approx \beta_1 \div S_{WFD}
\end{aligned}$$

$S_{WFD}$ is a reduction factor applied to the characteristic fatigue life of critical detail to account for variabilities in all structural tiers. The characteristic fatigue life of critical detail is statistically estimated from service/test data provided data are available. Otherwise, analytical methods which involve stress calculation and in-house durability analysis procedures will be used.

The shape or scatter parameter $\alpha$ is estimated based on test/service data. Data over the past twenty plus years have exhibited different $\alpha$ s for different structural tiers. In general, scatter in critical details within a component is smaller than that between components in an airplane, and the scatter between components is smaller than that between airplanes in a fleet. That is, $\alpha_1 > \alpha_2 > \alpha_3$. The following table lists the recommended $\alpha$ values for pressure and externally loaded structures at different structural tiers.

| | Pressure Loaded Structure | Externally Loaded Structure |
|---|---|---|
| Airplane | 5 | 4 |
| WFD Component | 6 | 5 |
| Critical Detail | 8 | 6 |

However, different $\alpha$ values may be used if test/service data demonstrate otherwise.

8.2.2 Crack Growth

Crack growth analysis starts with arranging the initial MED/MSD scenario. Initial lead flaw is normally placed in the most likely or stressed detail per stress analysis results or field observation. In the case that equally stressed details exist the lead flaw will be placed in the least inspectable detail for conservatism. Secondary flaws will be placed accordingly around the lead flaw and in the adjacent details.

LEFM theory is used for calculating the growths of multiple flaws simultaneously. Specifically, the Paris law is used in the crack growth calculation with a consideration of spectrum load wherever it is necessary. Average or typical material parameters in the Paris equation are used and crack growth is deterministically calculated.

The stress intensity factors for multiple cracks growth are based on superposition of geometry factors concerning crack interaction and load redistribution. For MSD in collinear rivet holes, e.g., MSD in lap splice, BCA employs a geometry factor that was derived from full-scale lap splice panel tests. This geometry factor is made for a tip-to-tip lead crack with MSD effects considered.

However, when fractography data of actual WFD is available, the empirical crack growth curves may be used.

8.2.3 Residual Strength

BCA uses an empirical knockdown factor for residual strength when MSD is present around a lead crack. In general, it tends to give a conservative result, especially when all cracks are of similar lengths.

At present time, however, BCA only calculates Point of WFD by limiting damage growth to a conservative crack length. For MSD such as lap splice cracking without broken frames, the lead crack is limited to 1 tip-to-tip. For MED such as broken frames without skin cracks, the damage is limited to three broken adjacent frames.

#### 8.2.4 Inspection Programs

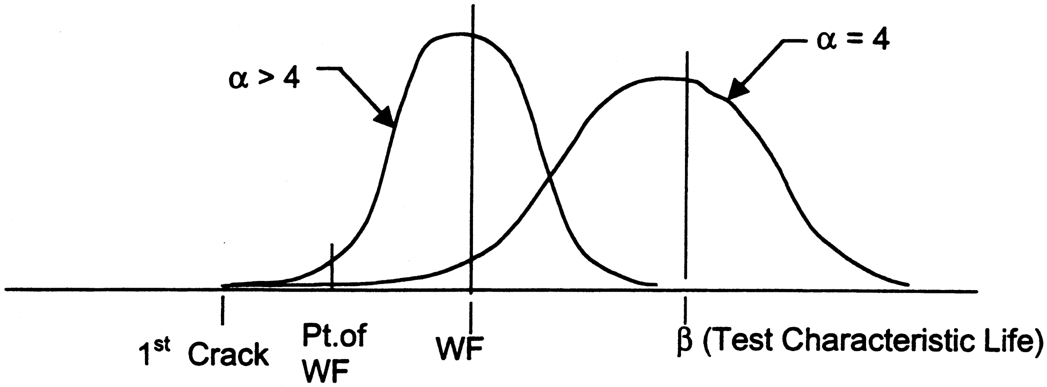
The inspection program will start at the MSD/MED initiation and end at Point of WFD. However, if there are sufficient number of airplanes inspected without evidence of WFD when the fleet leader reaches the end of program, Point of WFD may be justifiably extended.

Inspection methods and frequency will be determined based on BCA s Damage Tolerance Rating (DTR) system. This system will ensure timely detection of any MSD/MED in a fleet with a high probability of detection.

### *8.3 LOCKHEED-MARTIN AERONAUTICAL SYSTEMS*

For the long term, LMAS plans to use available test data and the results of a limited teardown inspection of a retired L-1011 airframe to develop equivalent initial flaw size (EIFS) data. EIFS distributions would be grown forward in time using conventional crack growth methods to predict WFD (either by a Monte Carlo simulation or probability of failure calculations). There is some evidence that recent improvements in the accuracy of small crack growth predictions can produce reliable EIFS distributions, dependent only on the material fastener combination and the crack growth methodology. However, this concept has not been sufficiently validated for 2024-T3 material, and the teardown program is still in the planning stages.

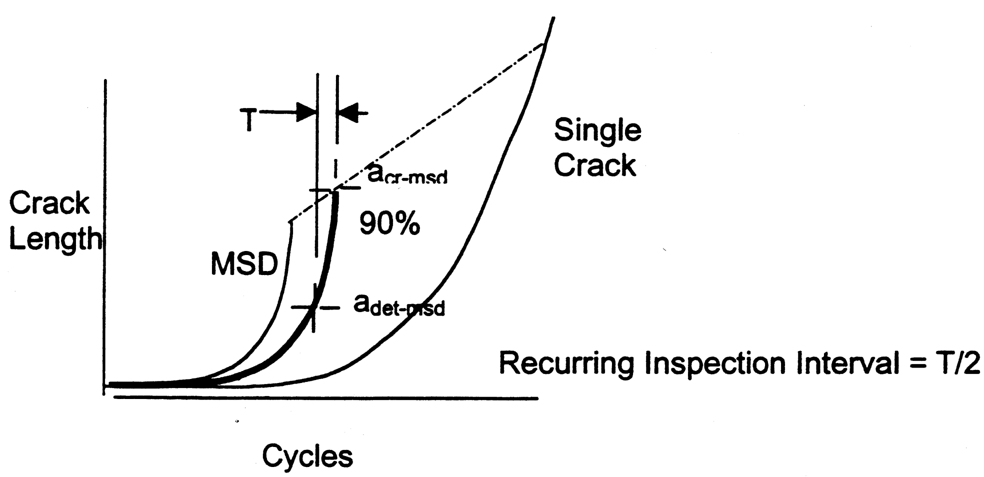
For the near term (until the EIFS concept has been validated), LMAS plans to use analysis based on the results of full scale, component, coupon tests to establish the characteristic time to crack initiation. For airplanes that have operated with stress spectra different from that applied to the test specimens (e.g., due to changes in usage), a test- demonstrated $K_t$ will be calculated from the test results and used with the actual spectrum to estimate the fatigue life. Historical trends regarding the expected scatter in the behavior of the details will be relied upon to estimate the time to first crack and time to threshold or Point of WFD . Currently, there is thought to be some difference in the scatter of structural details within a WFD-susceptible area when compared to non-WFD details. This difference has not been quantified, but the expectation is that within a WFD location, the scatter should be less. Therefore, to be conservative in the estimation of the WFD behavior, the larger scatter factors (based, for example, on a Weibull distribution with a shape parameter, $\alpha = 4.0$) will be used to calculate the time to first crack from the characteristic life. Then, to estimate the threshold behavior, a reduced scatter ($\alpha > 4$) will be used to calculate the time from first crack to the Point of WFD, as illustrated in the following sketch.




The time to first crack is the time until there is one crack (of a detectable size) expected to exist in the WFD location.

## 8.3.1 Crack Growth

In a WFD scenario, with an infinite number of possible configurations of cracks growing simultaneously, there would be a different crack growth curve for each of the configurations. The differences between the crack growth curves are more pronounced as the cracks get larger due to interaction between the adjacent cracks. This, unfortunately, is also the part of the curve used to determine the recurring inspection interval. Two assumptions will represent the upper and lower bounds of the range of possible crack growth curves. As shown in the sketch below, The single crack from a loaded hole with no other active crack tips will represent the slowest growth (least conservative assumption), and the other (most conservative) extreme is when adjacent holes are cracked both sides. A Monte Carlo simulation may be the best way to consider all of the possible curves between these extremes. For the present time, however, LMAS will use an assumption that will maintain simplicity by basing the analysis on a single crack growth curve, which will be more conservative than 90% of all possible curves between the extremes, as indicated in the sketch.



The stress intensity solution for the MSD case (all holes identically cracked) is based on the superposition of correction factors for interacting cracks with the solution for cracks at both sides of a loaded hole.

#### 8.3.2 Residual Strength

The residual strength is based on the link-up of adjacent cracks when the plastic zones touch. The Irwin equation is used to calculate the size of the plastic zones. The accuracy of predicting link-up with the Irwin equation has been shown to be dependent on the crack size and length of the ligament between the crack tips. A function is included with the Irwin model to effectively tune the link-up equation, and force agreement with the results of MSD residual strength tests across the full range of ligament lengths. At the present time, the tuning function has been developed for 2024-T3 aluminum only. Development of similar residual strength data for MSD cracks in 7075-T6 material is recommended.

#### 8.3.3 Inspection Programs

The preliminary action will be to alert operators to areas with WFD potential and request reporting of all service findings. The notification and reporting procedures to be used will be those recommended by the AAWG and implemented by the Structures Working Group. For those areas for which a Monitoring Period is appropriate an inspection program will be developed, terminating modifications will be developed for the other areas. Lockheed may elect to develop modifications which operators may incorporate as an alternate to MSD/MED inspections.

### 8.4 OVERVIEW OF DELTA AIR LINES METHODOLOGY

The WFD Assessment methodology used by an STC holder may be different than the OEM s because of the lower volume of details to be analyzed. An STC holder has less incentive to develop automated analysis methods or large amounts of material data. Instead, the STC holder will generally use generic software and material data from open sources. However, this reduced volume may also allow an STC holder to use analysis methods that may be more time consuming per detail than an OEM.

The Delta Air Lines approach is a fracture mechanics based methodology, designed to be adapted to a variety of MSD/MED geometries. This approach has been used for safety management in the past for several specific cases, and compares favorable with available OEM data. We also have a large amount of service data from our large and varied fleet (approximately 600 airplanes, with 8 different models, with sub-series) to provide additional validation between our analytical models and actual events.

This methodology overview is tailored for MSD in a lap joint, but it is applicable to any geometry in which MSD is expected in collinear fastener holes.

Note: A comprehensive understanding of fracture mechanics and details of the specific geometry, coupled with fleet reliability data is required to apply this general methodology to a specific case.

### 8.4.1 Initiation

The Initiation calculation determines the number of cycles required for cracks to reach 0.050 in. length. This calculation is a statistical analysis, based on coupon testing of similar MSD susceptible details. The result of the coupon testing is a characteristic life of the detail.

Based on this characteristic life and an assumed scatter for Al 2024, an Initiation Table of crack initiation times is created. This table lists the cycle intervals after which new cracks will initiate. The number of fastener holes assumed present determines the confidence level of the analysis.

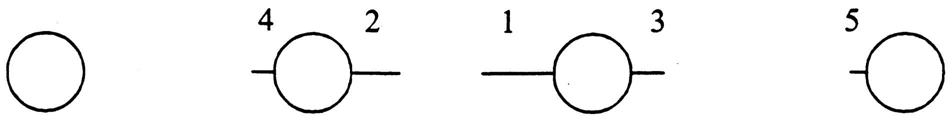
### 8.4.2 Crack Growth

Crack growth analysis is used to determine MSD crack lengths as a function of airplane cycle, starting from a 0.050 in. flaw. The crack growth analysis assumes a rationally conservative morphology of MSD cracks. It does not necessarily assume the worst case, but rather a cracking sequence which is conservative to some high degree of predetermined confidence.

Multiple cracks are grown using an iterative sequence of FEA models of the component. The initial model contains a single 0.050 in. crack from a hole in a high-stress location.

The succeeding model is the same, except the crack length is incremented one element longer. The stress intensity range is determined empirically by the energy released between models. Then the number of cycles required to reach the succeeding model can be calculated from da/dN[ΔK] data. Delta typically develops da/dN[ΔK] from non-proprietary sources such as Mil Handbook 5, or uses the in-house developed software incorporating Modified Forman equation and material data from NASA FLAGRO.

MSD cracks enter the model through the Initiation Table. As total cycle count reaches the next crack s initiation time in the Table, an additional 0.050 in. flaw is introduced into the model. New cracks are continually introduced as the analysis progresses. Each new crack is introduced at the worse location available, so the second crack will be an opposing crack in an adjacent hole. Generally, initiation sites continue outward from the first crack (Crack 1), as shown for five MSD cracks below.




The growth rates of all other cracks are linked to the rate of Crack 1. This linking allows cycle count between successive models to be a function of only the Crack 1 length throughout the analysis.

If MSD crack initiation occurs quickly compared to crack growth, then it is reasonable to simplify the analysis by assuming the worst case, that cracks initiate from both sides of every hole simultaneously. Under this scenario, only one hole must be modeled, with the cracked hole centered within a strip as wide as the fastener spacing. An analytical stress intensity function can be used for this strip model, instead of the FEA sequence empirical function.

### 8.4.3 Residual Strength

The residual strength criteria is based on the first link-up of two cracks from adjacent fastener holes. The link-up criterion is either the touching of the Irwin plastic zones or the yielding of the ligament between cracks, whichever occurs first. For the FEA empirical analysis, the plastic zones sizes and ligament stresses at limit conditions are checked at each iteration. For the strip model, ligament yield typically occurs first.

### 8.4.4 Inspection Threshold/Interval Determination

Inspection intervals are based on the detection of individual cracks with a 90% probability of detection, at 95% confidence. The inspection threshold is the time when a crack can first be detected, based on the crack initiation and crack growth to a detectable size. Time to initiation is based on the first cracking in the Initiation Table, factored down to account for variability among components and airplanes within a fleet.

The inspection window, from detectable to critical, is based on crack growth from detectable to the critical condition. The inspection interval is typically equal to this window divided by two, to allow two opportunities for detection.

## 8.5 ROUND ROBIN EXERCISES

In order to provide some insight for the regulators into the various methodologies presented in the previous section, round robin exercises were developed for the OEMs to try their methods.

Two examples were chosen for each OEM. The first is from the Boeing Company and the second from Airbus Industrie. Each example had been tested and test results were available for comparison to the OEM results. The round robins were done sequentially so that the experience gained from the first example could be applied to the second. Quantitative results are not presented here so that these examples might be used by other entities wishing to validate or confirm alternate analysis methods to their regulators.

Both examples deal with the subject of longitudinal lap splices.

### 8.5.1 Round-Robin Exercise Number 1

The first example, along with the requisite analysis data is shown in Figure 8.5.1. Airbus, Boeing, Lockheed Martin and Delta Air Lines all calculated the analysis parameters associated with establishing a maintenance program for MSD. All concluded that a Monitoring Period approach was valid for this particular example. Indeed all results derived were conservative with respect to the test results, however there was a significant disparity in the initial results. The AAWG then examined the reasons for the disparity. A total of nine separate areas of analysis were examined to determine where significant differences existed. In was determined that the differences in the results could be attributed to inconsistency in the use of the following parameters.

### Key Parameters for MSD / MED Analysis

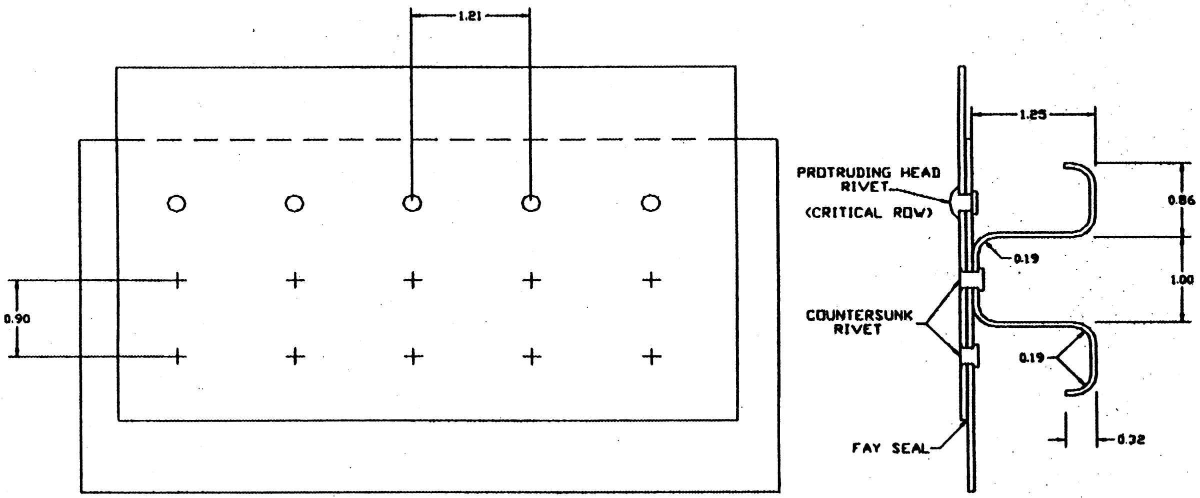
- Flaw size assumed at initiation of crack growth phase of analysis
- Material properties used (static, fatigue, fracture mechanics)
- Ligament failure criteria*
- Crack growth equations used
- Statistics used to evaluate fatigue behavior of the structure (e.g. time to crack initiation)*
- Means of determining Point of WFD*
- Detectable flaw size assumed*
- Initial distribution of flaws
- Factors used to determine lower bound behavior as opposed to mean behavior

Of the nine, the ones marked with an asterisk were considered the most significant in producing results that were different.

### 8.5.2 Round-Robin Exercise Number 2

The second round robin exercise, Figures 8.5.2 through 8.5.4 was conducted with the first results in mind. A set of ground rules was developed to try and minimize the disparity in the results. These ground rules were determined as shown Figure 8.5.5. In order to do some comparisons, both in-house and specified procedures were requested.

The analysis of the structural detail described in figures 8.5.2 through 8.5.4 was conducted based on coupon test results. The actual detail was tested in a full-scale test and the test results were made available to the participants after the analysis was completed. The results of round-robin number 2 showed fairly good agreement between each of the four OEMs and one airline that participated. The results were not in good comparison to the test however. Further discussion revealed that an additional factor was omitted from the analysis, that being an adjustment between coupon to full scale test. When this factor was applied to the analysis numbers reasonable answers were obtained. Figure 8.5.6 is included to show this effect in a general way. The reader is cautioned that these factors are highly dependent on design configuration, testing protocol, and other factors. A discussion of these scatter factors and mean life tendencies is detailed in section 8.5.3. Coupon to full scale test results could mean a factor on stress of as much as 1.3 or a factor on life of three. These factors have been verified through a number of manufacturer test comparisons.




**SKIN**
2024-T3 CLAD SHEET
t = 0.063 in
Phosphoric Acid Anodized
Fay Surface Seal

**STRINGER**
7075-T6 BARE SHEET
t = 0.056 in

**PROTRUDING HEAD RIVET**
MS20470DD
Hole Size = 0.19 1 - 0.202 in
Diameter = 0.1875 in
Head Size = 0.394 in
Bucked Head Size = 0.2625 in
2017 Aluminum
Hand Driven

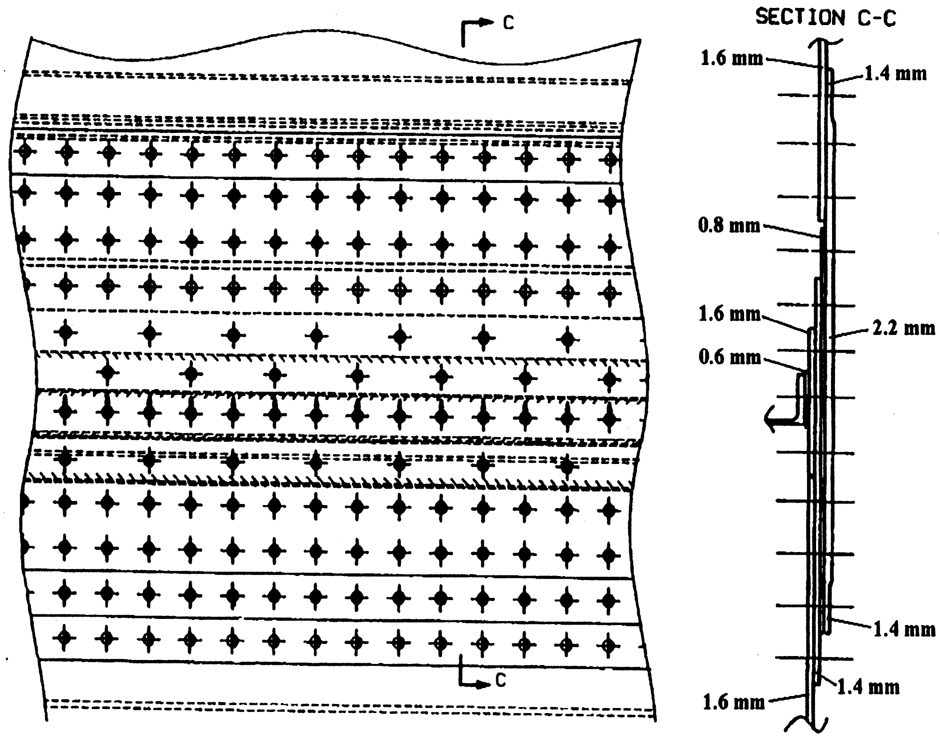
**COUNTERSUNK RIVET**
NAS1097
Hole Size = 0.190 - 0.196 in
Diameter = 0.1875 in
Head Size = 0.298 in
Bucked Head Size = 0.2625 in
2017 Aluminum
Hand Driven

Airplane Radius = 127 in
Frame Bay Spacing = 20 in
$\sigma$ = 15 KSI (0.85*pr/t as verified by strain gage stresses at midbay due to load redistribution)
Limit Load Pressure = (Cabin Pressure + Aerodynamic Load)*1.15 = (8.9 + 0.9)*1.15 = 11.3 PSI
Limit Load Case = 0.85*11.3*127/0.063 = 19 KSI

Figure 8.5.1 — Longitudinal Lap Splice Structural Detail — Example 1

# AAWG Round Robin

## Example Lap Joint Repair




skin material 2024T3
Surface treatment
chromic acid anodizing plus primer
wet assembly and wet riveting
with sealing

**Rivet pitch and distance of rivet rows: 24 mm**

| | | |
|---|---|---|
| RIVET | ● | NAS1097D06 |
| RIVET | ○ | NAS1097D05 |
| RIVET | ◐ | NAS1097D05 |

Figure 8.5.2 — Lap Joint Repair — Example 2

# AAWG Round Robin Exercises
# Example 2 – Details

Full scale fatigue test
(fuselage radius 2820 mm)
$\sigma_{max}$= 96 MPa in 1.6 mm skin in the center between the frames, R=0 (test stress, circumferential)
limit load stress $\sigma_{limit}$ = 110 MPa
limit load occurs once per life time
Characteristic life of Critical Detail:
average fatigue life of flat coupon specimens (width 160 mm) up to failure
N = 260000 cycles for $\sigma_a$ = 48 MPa, R = 0.1
standard deviation: s = 0.19

Skin
2024 T3 clad
t=1.6 mm
Chromic acid anodized
plus primer
wet assembly and wet riveting with sealing
including faying surface
Doubler and shim material 2024T3 clad

Countersunk Rivets in Lap Joint Repair
NAS 1097 DD5 (solution heat treated)
Diameter: 4.0 mm
Head Size: 6.27 mm
Bucked Head Size: 5.6 - 7.5 mm
Material: Al 3.1324T31

NAS 1097 DD6 (solution heat treated)
Diameter: 4.8 mm
Head Size: 7.67 mm
Bucked Head Size: 6.7 - 8.7 mm
Material: Al 3.1324T31

The WFD evaluation is requested for the skin at the run-out of the repair doubler and shims, respectfully.

| | |
|---|---|
| Skin stress in the center of a frame bay | 100 percent |
| Skin stress at 1/4 length of the frame bay | 97 percent |
| Skin stress at 3/4 length of the frame bay | 97 percent |
| Skin stress close to the frame | 89 percent |

Figure 8.5.3 — Round Robin Example 2 — Analysis Data

Battelle 2024-T3 tabular data from the Damage Tolerant Design Handbook, Volume 3, page 7.5-94 compiled by UDRI for the USAF and dated December 1983. (For grain orientation: L-T, room temperature lab air environment, R-ratio = 0.0)

The two "endpoints" of this data were fit to the Paris equation to come up with the following:

da/dN = c*deltaK **n
where c=$5.6153*10^{-11}$ and n=4.4323
da/dN = ($5.6153*10^{-11}$)*(deltaK**4.4323)

Which yields the following tabular data points (in English units, inch & ksi):

| DeltaK | da/dN |
|---|---|
| 0.5 | $2.601*10^{-12}$ |
| 4.00 | $2.6175*10^{-8}$ |
| 16.84 | $1.53*10^{-5}$ |
| 35.36 | $4.10*10^{-4}$ |
| 100.0 | $4.111*10^{-2}$ |

Figure 8.5.4 — Round Robin Exercise 2 — da/dN Data

## Figure 8.5.5 GROUND RULES FOR AAWG-TPG ROUND ROBIN EXERCISE Number 2

The following are the general ground rules to be followed in completing the round-robin exercise.

- Airbus to provide geometry, mean life, standard deviation and other pertinent data by December 14, 1998.
- Each Participant will supply four sets of answers according to the following:

| *Without Fleet Variability* | *With Fleet Variability* |
|---|---|
| In-house Procedures | In-house Procedures |
| As Specified Procedures | As Specified Procedures |

- Use Mil-Handbook 2024-T3 data.
- Number of defects per airplane = 2
- Number of airplanes in fleet =50 A/P
- For specified procedure use Airbus POD curve with 6mm 95% POD
- For specified procedure assume flaw size at initiation equals 1 mm
- For specified procedure failure criterion is WFD in one frame bay.
- For specified procedure use Paris crack growth law.
- For specified procedure use $WFD_{point}=WFD_{ave}/2.0$
- For specified procedure use Inspection Start Point = $WFD_{ave}/3.0$
- Use in-house procedure for initial damage distribution.

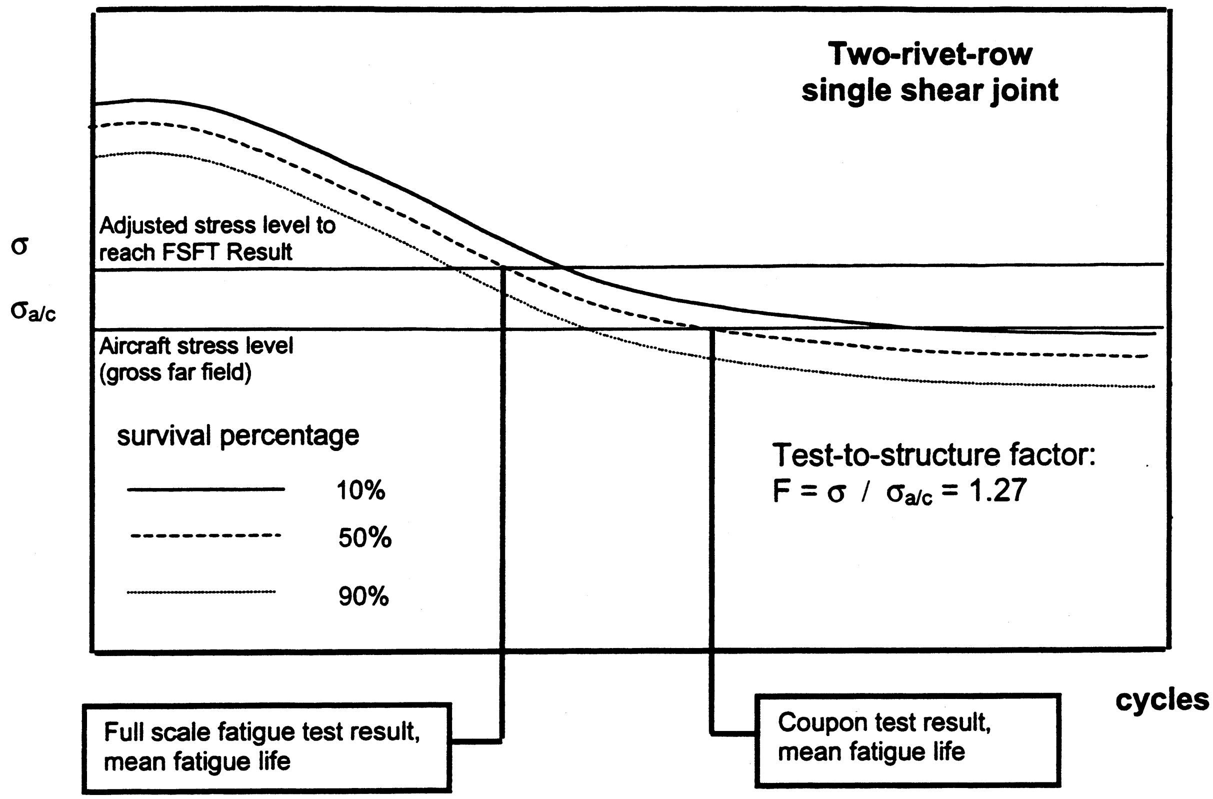



Figure 8.5.6 Typical Coupon Test —To — Full Scale Test Factor

<u>8.5.3 Scatter Factors And Mean Life Tendencies For MSD Crack Initiation</u>

In Appendix A of the 1993 report of the Industry Committee on Widespread Fatigue Damage, the factors to be considered when correlating test data to in-service airplanes were listed, as follows:

1. *<u>Stress spectrum</u> - adjustment may be accomplished using a combination of proven analysis methods and appropriate SN data or by comparative testing.*
2. *<u>Boundary conditions</u> - account for variations of stress levels and distributions at specific locations resulting from unrepresentative boundary conditions or load applications.*
3. *<u>Specimen configuration effects</u> - consideration of the effect of the number or repetitive fatigue sites in a specimen on the average initiation life and scatter band.*
4. *<u>Material aspects</u> - account for differences in material specification and appropriate process treatments.*
5. *<u>Specimen geometry</u> - conditions such as load transfer, type of fastener, secondary bending and pre-stress should represent the actual airplane configuration or be accounted for by an appropriate factor.*

6. *Environmental effects - the effects of environmental conditions should be recognized.*
7. *Scatter - scatter in test results caused by variations in specimens, test conditions and testing techniques (such as cycle rate) should be accounted for.*

Apart from item number 3, each of the considerations detailed in the above list are related to possible differences between a fatigue test specimen (either coupon, component or full-scale) and the actual behavior of the in-service airplane. The central assumption underlying the use of test evidence in predicting airplane structural fatigue is that the experimental results, usually obtained from laboratory tests on simple coupons, are representative of the airframe under service conditions. The aging airplane problem introduces additional concerns as to the validity of this assumption, such as

- For airplane types manufactured over a long period, *e.g.* more than ten years, it is likely that variations will occur in the production procedure and standard, and existing fatigue test evidence may become unrepresentative of the in-service airplane.
- Fatigue test results generated on simple coupons are unlikely to include any useful information on environmental effects such as corrosion, which are central to ensuring the continued airworthiness of the airframe.

It is generally recognized that full-scale fatigue test evidence is more accurate than the results of major component tests or coupons tests in predicting the fatigue endurance and the associated scatter factor for airframe structural components. Coupon or component test specimens are more likely than full-scale test specimens to have manufacturing processes, boundary conditions, and secondary load effects that are unrepresentative of in-service airplanes. The experimental techniques adopted during coupon or components tests, such as the environmental conditions and the cycle rate, may also be significantly different to that experienced by the airplane during operational service.

The third factor in the Industry Committee list was specifically intended to address the effect of an increase in the number of fatigue critical locations (of the same geometry and applied stress spectrum) on fatigue endurance and the associated scatter. Fatigue test results clearly show that first crack initiation occurs sooner in a group of identical repetitive details than in a single detail, provided that everything else (*e.g.* loads, specimen build standards, *etc.*) remains constant. In the case of multiple site damage and multiple element damage, the effects of load redistribution may accentuate this reduction in fatigue life.

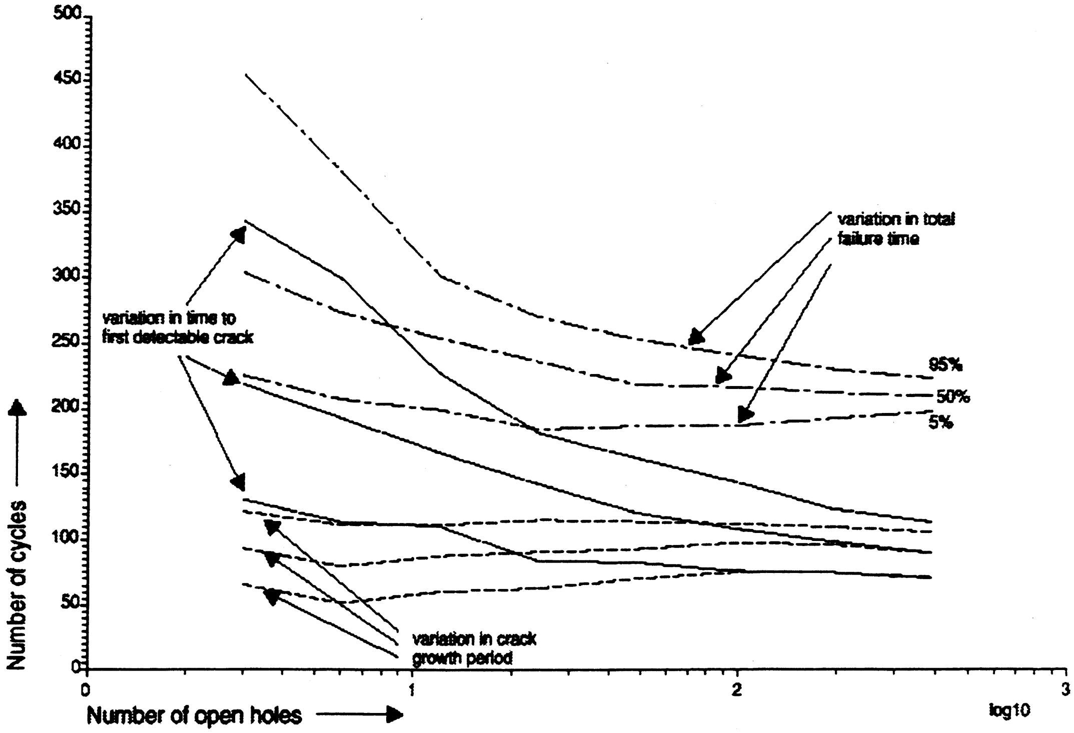



Figure 8.5.3.1 - Statistical analysis of multiple open hole specimen.

The relationship between the probability $p_s$ of fatigue crack initiation at a single site and the probability $p_{1:n}$ of at least one such event occurring within an arbitrary number of sites $n$ may be obtained through a simple order statistics analysis, which gives

$$p_{1:n} = 1 - ( 1 - p_s )^n \qquad (1)$$

This expression is independent of the nature of the probability distribution function used to model $p_s$ (lognormal, Weibull, *etc.*). Hence, given a probability distribution function for $p_s$, the probability that at least one crack has developed in $n$ potential sites (there are generally two potential sites per hole), at any specified time, may be easily obtained. The mean duration for at least one crack to initiate decreases with increasing $n$; the scatter in this duration (defined for example by –95% confidence limits) also decreases as $n$ increases. An example of this behavior is shown in Figure 8.5.3.1, which gives the results of a Monte Carlo analysis of a multiple open hole specimen. A significant reduction in the mean time to the development of first detectable crack may be observed as the number of holes increases, along with a parallel reduction in the separation between the 95% confidence limits. In this example, there is not a corresponding decrease in the crack growth period between crack initiation and coupon failure.

It should be noted that the basic input is the probability of a crack initiation event occurring at a single site. If a probability distribution for initiation were defined from tests upon a simple single-hole coupon, for example, there would usually be two equally likely potential sites for crack initiation. Therefore, the distribution for $p_s$ may be readily obtained by applying a correction to the probability distribution for the single-hole coupons, using the above expression with $n=2$. Obviously, a modification of this procedure can be applied to coupons with more than one fastener hole. A more general expression can be derived for at least $m$ initiation events within $n$ potential sites ($m < n$). However, the simple statistical approach breaks down in the presence of crack growth, since additional cracks are rapidly induced by load redistribution. Experience shows that the general expression can be used for $m=2$ or $3$ to a reasonable accuracy. The prediction of larger numbers of newly initiated cracks requires a more representative model incorporating both the initiation and the fatigue crack growth stages.

# 9.0 AIRPLANE SPECIFIC TIMETABLE RECOMMENDATIONS FOR COMPLETION OF AUDIT

## 9.1 AIRPLANE FLEETS AT RISK

The scope of this WFD structural evaluation has been expanded from the initial eleven (11) Aging Fleet models identified in the AAWG Final Report on Structural Fatigue Evaluation dated October 14, 1993 (Reference [3]). It now includes all large transport category airplanes having a maximum take-off gross weight (MTOGW) greater than 75,000 lbs., which have been certified to pre-or post-Amendment 45 standards.

In order to ensure that the WFD evaluation is completed in a timely manner with respect to the actual service life accumulated to-date, the following fleet selection criterion has been established based on the Design Service Goal (DSG) or the Extended Service Goal (ESG):

WFD Evaluation Priority

| Category | Fleet Status | Required Action |
|---|---|---|
| A | > 100% DSG or ESG | Expedite WFD program implementation by Dec 31, 2001 See Section 10 |
| B | > 75% DSG or ESG | WFD program development should have begun |
| C | > 50% DSG or ESG | Initiate preliminary planning for WFD program development |

Any fleet status below 50% DSG/ESG does not require action at this time. The number of airplanes in each priority category is documented in Tables 9.1and 9.2, to assist in prioritizing industry action.

These tables list passenger and freighter airplanes in chronological order of certification date, relating to pre- and post-amendment 45 status. However, they exclude Russian and Japanese airplanes and other models having fewer than ten airplanes in commercial service. Values of MTOGW are also integrated into these tables for the respective fleet types as well as the current number of airplanes in service.

## Table 9.1 Large Transport Category Airplanes Certified Pre-Amendment 45

| AIRPLANE | Initial Certification Information | | | Number in Service | DSG 1000 LDGS | ESG 1000 LDGS | WFD* Audit Completion Date | Number of Airplanes In Each Category | | | Models |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CERT DATE | PAX | MTOGW 1000lb. | | | | | A >100% D/ESG | B >75% D/ESG | C >50% D/ESG | |
| L188 | Aug-53 | 74 | 116 | 39 | N/A | N/A | NP | ? | ? | ? | Electra |
| B707 | Sep-58 | 174 | 280 | 197 | 20 | N/A | 12-31-01 | 110 | 179 | 179 | -100,-300 |
| DC8 | Aug-59 | 139 | 276 | 300 | 25 | 70 | 12-31-01 | 0 | 17 | 103 | -10,-20,-30,-40,-50,-50F,-60,-60F,-70, -70F |
| B720 | Jun-60 | 149 | 230 | 11 | 30 | N/A | 12-31-01 | 4 | 9 | 10 | 720,720B |
| B727 | Dec-63 | 125 | 161 | 1525 | 60 | N/A | 12-31-01 | 24 | 474 | 1060 | -100,-100C,-200,-200F |
| BAC111 | Apr-65 | 99 | 104 | 106 | 55 | 85 | NP | 0 | 10 | 43 | |
| DC9 | Nov-65 | 90 | 79 | 862 | 40 | 100 | 12-31-01 | 4 | 198 | 600 | -10,-10F,-20,-30,-30F,-40,-50 |
| B737 | Dec-67 | 99 | 98 | 1021 | 75 | N/A | 12-31-01 | 31 | 233 | 528 | -100,-200,-200C |
| F28 | Feb-69 | 55 | 65 | 204 | 60 | 90 | 12-31-01 | 0 | 13 | 56 | |
| B747 | Dec-69 | 450 | 713 | 1048 | 20 | N/A | 12-31-01 | 96 | 243 | 491 | -100,-200 |
| DC10 | Jul-71 | 270 | 430 | 413 | 42 | N/A | 12-31-01 | 3 | 52 | 241 | -10,-30,-30F,-40 |
| L1011 | Apr-72 | 400 | 474 | 214 | 36 | N/A | 12-31-01 | 4 | 33 | 136 | -1, -14, -15, -3 |
| A300 | Mar-74 | 345 | 301 | 230 | 48/40/34 | N/A | 12-31-03 | 0 | 13 | 76 | B2, B4-100, B4-200 |
| Concorde | Jan-76 | 100 | 407 | 13 | 6.7 | 8.5 | NP | 0 | 5 | 2 | |
| MD80 | Aug-80 | 155 | 140 | 1145 | 50 | N/A | NP | 0 | 47 | 217 | -81,-82,-83,-87,-88 |
| B747 | Mar 83 | 450 | 833 | 471 | 20 | N/A | NP | 0 | 0 | 467 | -300, -400 |
| B737 | Nov 84 | 159 | 140 | 1880 | 75 | N/A | NP | 0 | 0 | 21 | -300, -400, -500 |
| A300# | Jun 86 | 345 | 363 | 213 | 30 | N/A | 12-31-03 | 0 | 2 | 16 | -600, -600R, -F4-605 |

\# - Certified pre Am 45, Analysis to Post Am 45 Standards
* Program ready to be incorporated into operators maintenance programs. Programs currently under development are voluntary OEM Programs.
NP — None Planned at this time

## Table 9.2 Large Transport Category Airplanes Certified Post Amendment 45

| AIRPLANE | Initial Certification Information | | | Number in Service | DSG 1000 Ldgs | ESG 1000 Ldgs | WFD Audit Completion Date | Number of Airplanes In Each Category | | | Models |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CERT DATE | PAX | MTOGW 1000lb. | | | | | A >100% D/ESG | B >75% D/ESG | C >50% D/ESG | |
| B767 | Jul-82 | 210 | 315 | 663 | 50 | N/A | NP | 0 | 0 | 28 | -100,-200,-300 |
| B757 | Dec-82 | 185 | 250 | 780 | 50 | N/A | NP | 0 | 0 | 4 | |
| BAe146 | Feb 83 | 90 | 84 | 315 | 50 | N/A | NP | 0 | 0 | 2 | |
| A310 | Mar-83 | 275 | 291 | 251 | 40 | N/A | NP | 0 | 0 | 4 | |
| F100 | Nov-87 | 107 | 98 | 276 | 90 | N/A | NP | 0 | 0 | 0 | |
| A320 | Feb-88 | 150 | 150 | 584 | 48 | N/A | NP | 0 | 0 | 0 | |
| MD11 | Jul-90 | 320 | 602 | 167 | 20 | N/A | NP | 0 | 0 | 0 | |
| A340 | Dec-92 | 440 | 567 | 115 | 20 | N/A | NP | 0 | 0 | 0 | |
| A330 | Oct-93 | 440 | 467 | 61 | 40 | N/A | NP | 0 | 0 | 0 | |
| A321 | Dec-93 | 220 | 183 | 75 | 48 | N/A | NP | 0 | 0 | 0 | |
| MD90 | Nov -94 | 172 | 156 | 59 | 60 | N/A | NP | 0 | 0 | 0 | -30 |
| B777 | Apr 95 | 300 | 650 | 89 | 44 | N/A | NP | 0 | 0 | 0 | |
| A319 | Apr-96 | 145 | 141 | 45 | 48 | N/A | NP | 0 | 0 | 0 | |
| Gulfs- V | Apr 97 | 19 | 90.5 | 30 | 40 FH | N/A | NP | 0 | 0 | 0 | |
| Bom GE | Aug 98 | 19 | 93.5 | 0 | 15 | N/A | NP | 0 | 0 | 0 | |
| F70 | Oct 94 | 80 | 85 | 15 | 90 | N/A | NP | 0 | 0 | 0 | |

NP — None Planned at this time

## 9.2 LEAD TIME ISSUES FOR TERMINATING ACTIONS

### 9.2.1 Introduction

During operator presentations to the Authorities Review Team (ART) at Gatwick, England in March 1998, the AAWG was asked to provide additional information to help with the understanding of issues surrounding lead time for modifications (e.g. parts, planning, etc.) that operators need prior to implementing terminating actions.

### 9.2.2 Discussion

Since a Monitoring Period is an integral element of the AAWG s recommendations for the evaluation and safety management time during which MSD/MED may occur in the fleet, it is important to understand the necessary planning factors that operators will face prior to accomplishing terminating actions.

To illustrate the impact on the operators, a hypothetical narrow-body fuselage lap joint modification scenario will be used. For this case, it is assumed that small MSD cracks have been experienced in high time airplanes during an implemented monitoring period. The operator impact for anticipated terminating action for a scenario such as this, would be approximately 10,000 hours labor, and up to 40 days out-of-service time for each airplane. For a major carrier, with a large fleet of airplanes, the operational impact would be very significant. For one operator s fleet of 74 airplanes, this equates to over 8 years cumulative time to accomplish airplanes at a single airplane rate, which coincides to a typical HMV or D-Check cycle. Any faster accomplishment would place the terminating action out of phase with normal heavy maintenance visits, and would result in a large number of flight cancellations. Flight cancellations would also occur if the work were scheduled at the normal HMV rate, since the elapsed time would be extended approximately two weeks. Since HMV s are usually scheduled in succession, without gaps, a domino effect on flight cancellations occurs once planned down times are interrupted.

Terminating action for typical fuselage lap joints would require the manufacture of long curved panels, used to replace the original joints. The length required for full skin joint replacement may be beyond normal raw stock sizes, and special mill-runs could be required. Special tooling is often required to contour panels within specified tolerances, using manufacturing processes beyond the capability of most operators. Lead times for the manufacture of such parts can easily require 9 to 12 months. Additional preparation involves facilities, work platforms, jacks, contour shoring for airplane jig position support, and training of sheet metal technicians to perform the work (difficult thin sheet riveting). And lastly, since the labor required to perform such a modification could exceed industry capacity, additional technicians (mechanics), inspectors, work schedulers, materiel planners and Liaison Engineers would have to be hired, or alternatively work out-sourced to a mod center. During this planning and implementation period, as many as 20,000 additional flight cycles could accrue on the fleet, which must be accounted for in the WFD estimate. Alternatively, work would have to begin on airplanes well below the identified MSD/MED threshold, to meet proposed compliance times.

One other consideration is validation of the proposed terminating action. In the cited demonstrative case, several repair and modification scenarios are envisioned. Each would require extensive full-scale fatigue testing to avoid future service actions on the part of the operators.

### 9.2.3 Structures Task Group Process

For the fuselage lap joint example cited to illustrate lead-time issues, the following operator concerns should be addressed through the Structures Task Group operator-OEM advisory process:

- A summary of the fleet data and metallurgical data gathered from typical excised cracks, forwarded by operators to the OEM, should be made available to other operators and FAA
- Crack growth curves for the MSD condition should be made available to the operators and FAA
- Advance copies of any modification service bulletin should be made available to the operators as soon as possible to allow the operator planning process to proceed
- SRM revisions to cover FAA approved repair configuration should be readied
- OEM should provide preformed (contoured and curved) modification parts through a equalitarian distribution process
- Service bulletins should include instructions on the logistics of accomplishing specific repairs (specific shoring recommendations, other structural components that can be removed, what other types of simultaneous maintenance activity can be performed concurrently with the modification)
- Faying sealant with long cure times should be utilized to allow installation time without premature curing/hardening of the sealant
- Specific manufacturing process instructions for forming parts should be provided by the OEM
- Service bulletins for terminating action for airplanes under threshold should also be provided to preclude the potential for more substantial future work
- Specific instructions for door opening interfaces with modification parts should be provide in any service action on fuselage lap joints
- Access/removals of electrical systems such as circuit breaker or instrument panels must also be addressed to allow adequate access to the crown area in the forward fuselage area

- Previously repaired joints must also be dispositioned (damage tolerance evaluation supported by fatigue test)
- Aerodynamic performance penalties associated with the installation of protruding head fasteners and external modification parts entire length of fuselage at multiple joints, and effects on airplane stall measurements and characteristics (if fuselage drag is significant) must also be addressed prior to release of terminating action including these design features
- Compliance recommendations should be quantified for differences in fatigue crack initiation and crack growth between different airplane models, i.e. passenger and freighter models.
- Industry facility and skilled personnel capacity should also be evaluated in determining compliance times.
- Compliance times should also consider existing operator scheduled maintenance visits
- Terminating action plans should include compliance flexibility
- OEM compliance recommendations should be based on actual fleet service data
- Compliance times should be implemented for different zones of the fuselage based on stress severity if applicable to support packaging of work
- Long term durability of the terminating action should accurately replicate service conditions with full scale fatigue test

Special task oriented working committees comprised of the airline representatives and OEM should be utilized to discuss lead time and planning complex issues associated with WFD terminating actions.

### 9.2.4 Summary

A safety management program example using a hypothetical narrow-body fuselage lap joint MSD/MED problem has been used to illustrate potential lead time and planning issues. It is anticipated that approximately 12 months may be necessary to resolve all planning issues associated with terminating action for such a fleet scenario. Any significant WFD terminating action must allow significant planning time for operators and OEM s to resolve the myriad of anticipated (and typical) problems highlighted in the previous section.

# 10.0 REGULATORY OPTIONS AND ANALYSIS

This task establishes options that the FAA or other regulators can use to make OEMs, STC holders and operators comply with WFD audits of specific models if voluntary means fail since WFD is an airworthiness concern.

## *10.1 REGULATORY OPTIONS*

Possible regulatory actions identified by the AAWG include the following options:

- Task ARAC to develop FAR 121 Operating Rule and Guidance Advisory Circular
- Issue FAR 25.1529 rule change requiring OEMs to develop new airworthiness limitations for WFD prone design details.
- Issue model specific airworthiness directives to require modification of identified WFD prone design details.
- Issue model specific airworthiness directives to require inspection of identified WFD prone design details.
- Issue FAR 121 Operating Rule to require operators to revise their maintenance programs to include additional Supplemental Structural Inspection Programs.
- Issue model specific airworthiness directive to mandate flight cycle service limitations
- Revoke production certificate of non compliant OEM
- Limit production of spare parts by noncompliant OEM
- Increase OEM liability for the type design.

## *10.2 RELATIVE MERITS OF EACH OPTION*

The advantages and disadvantages of each regulatory option in establishing effective WFD prevention are listed in the Tables 10.1 through 10.10.

Table 10.1 — Relative Merits of Regulatory Options

Task ARAC to develop FAR 121 Operating Rule and Guidance Advisory Circular

| Option | Advantages | Disadvantages |
|---|---|---|
| Task ARAC to develop FAR 121 Operating Rule and Guidance Advisory Circular | Rulemaking is more appropriate than AD, if WFD is not an immediate airworthiness concern | Long time to develop, mandate and implement program |
| | Single rule can cover all affected airplane types<br>Rulemaking process provides firm notice of intentions in time to consider courses of action | Limited technical content without OEM Participation<br>Will not address fleet types or design details of immediate airworthiness concern |
| | Industry infrastructure (model specific) already exists to develop and implement WFD program with AAWG oversight | Costly to operators (may be necessary for operator to bear entire cost of program development) |
| | | Limited industry technical skills available to develop program without OEM participation |
| | | Limited industry ability to validate program without OEM participation |
| | | Uniform compliance among all global operators questionable |
| | | Variations in program development and implementation between fleet types . |

Table 10.2 — Relative Merits of Regulatory Options
Issue airworthiness directives to require modification of WFD prone design details

| Option | Advantages | Disadvantages |
|---|---|---|
| Issue airworthiness directives to require modification of WFD prone design details | Not dependent on development of inspection program | Problem not rigorously demonstrated by analysis for each model specific detail resulting in overly conservative thresholds |
| | Very effective (addresses all design details of concern) | Most costly option to operators |
| | Global acceptance | Long out-of-service times required to accomplish modifications |
| | Permanent Fix | Extensive analysis and validation required to identify modifications beyond part replacements |
| | | Arbitrary compliance time without rigorous analysis (may be unconservative) Problems with materials without OEM participation |
| | | Special skill requirements to replace parts to original build standards |
| | | Long lead times on parts and tooling |
| | | Limited modification facilities (industry operating at current capacity) |
| | | Limited shoring and tooling available to put airplanes into jig position for modification |
| | | Extrusions or forgings may be obsolete |
| | | Special fastener and coldworking tool shortages |
| | | Airplanes already beyond DSG |

Table 10.3 — Relative Merits of Regulatory Options

Issue FAR 25.1529 revision requiring OEMs to develop new airworthiness limitations for WFD prone design details

| Option | Advantages | Disadvantages |
| --- | --- | --- |
| Issue FAR 25.1529 revision requiring OEMs to develop new airworthiness limitations for WFD prone design details | Precedence for rulemaking, i.e. existing certification requirement | Dependent on OEM participation |
| | Requires analysis of individual design details instead of shot-gun approach | Long time to develop, mandate (requires regulatory harmonization) and implement program |
| | OEM Rule | |
| | Covers old and new certification programs | Will not address fleet types or design details of immediate airworthiness concern (additional rulemaking required) |
| | Recertification required beyond fixed service limit | Requires additional rulemaking to address repaired structure |
| | Applicable to STC s | Options dependent on the development and validation of NDI technology |

Table 10.4 — Relative Merits of Regulatory Options

Issue model specific airworthiness directives to require inspection of WFD prone design details

| Option | Advantages | Disadvantages |
|---|---|---|
| Issue model specific airworthiness directives to require inspection of WFD prone design details | Addresses all design details | Requires development of extensive inspection program (identification of critical flaw sizes and locations) and validation of NDI techniques |
| | Addresses specific fleets of concern | Limited technical merit without OEM participation |
| | Rapid implementation | Must be demonstrated airworthiness concern |
| | Perception of doing something | Assures only short term airworthiness (arbitrary probability of detection leading to missed cracks) |
| | | Doubtful global effectiveness (Large areas to be inspected) |
| | | Conservative inspection intervals necessary without extensive analysis |
| | | Very costly (NDI equipment/schedule disruptions/excessive analysis) |
| | | NDI technology may not be ready |
| | | Specific skills required to apply |
| | | Limited availability of specialized NDI equipment |
| | | No permanent fix |
| | | Unacceptable risk associated by management of MSD/MED with only inspections |
| | | Some design details may not be inspectable (hidden details) |

## Table 10.5 — Relative Merits of Regulatory Options

Issue a FAR 121 Operating Rule requiring incorporation of new Supplemental Structural Inspections into operators maintenance program

| Option | Advantages | Disadvantages |
|---|---|---|
| Issue a FAR 121 Operating Rule requiring incorporation of new Supplemental Structural Inspections into operators maintenance program | Rule is more appropriate than airworthiness directive since immediate airworthiness concern has not been demonstrated | Long time to develop, mandate and implement program requiring |
| | Precedence for SSIPs | Will not address immediate airworthiness concerns |
| | Covers all concerned fleets with singe rule | Inflexible (slow process to revise rule if needed) |
| | Existing industry infrastructure (model specific STG s) to develop program with AAWG oversight | Requires OEM participation to develop effective large scale program (many design details) |
| | Addresses only specific design details shown by analysis to be of WFD concern instead of shot-gun approach | Requires rigorous analysis and data, along with validation |
| | Operator options to customize program to their mission and maintenance program using program guidelines | Requires FAA PMI oversight for uniform application |
| | Establishes service limit for noncompliance | Arbitrary compliance time to address the effect of repairs and design changes |
| | | Requires rigorous inspection program and NDI development |
| | | Requires threshold validation |
| | | Does not address design details that cannot be reliably managed with inspections |

Table 10.6 — Relative Merits of Regulatory Options
Issue model specific airworthiness directives to mandate operational limitations

| Option | Advantages | Disadvantages |
|---|---|---|
| Issue model specific airworthiness directives to mandate operational limitations | Can be issued quickly to address immediate airworthiness concern | Effectiveness difficult to determine without analysis |
| | Could be used to extend service life | Could impact other safety areas (ex. Air Traffic Control) |
| | Ensures global action | Negative publicity for operator and regulators (Certification deficiency implied) |
| | Does not rely on inspection of large areas | Limits mission of the airplane |

Table 10.7 — Relative Merits of Regulatory Options
Issue model specific airworthiness directive to mandate flight cycle service limitations

| Option | Advantages | Disadvantages |
|---|---|---|
| Issue model specific airworthiness directive to mandate flight cycle service limitations | Addresses immediate airworthiness concern | Economic disadvantages to operators |
| | Total safety ensured, if retirement set to right value (flight cycle limit) | Limit must be set to conservative flight cycles without rigorous analysis |
| | Fleet strategic planning simplified | Safe life may be misconstrued to mean that airplanes are safe without continuing surveillance and assessment |
| | | May result in less maintenance as airplanes approach fixed retirement cycle limit (increase in deferred maintenance) |
| | | Production capacity limits mass replacement of large number of airplanes |

Table 10.8 — Relative Merits of Regulatory Options
Revoke production certificate of noncompliant OEM s

| Option | Advantages | Disadvantages |
|---|---|---|
| Revoke production certificate of noncompliant OEM s | Provides economic incentive to OEM to complete WFD program | Not Effective, if OEM is forced out of business<br><br>Adverse impact on safety if OEM is out of business<br><br>Not in public interest<br><br>Does not improve safety (airplanes of concern still operating)<br><br>Legal constraints for implementation |

Table 10.9 — Relative Merits of Regulatory Options
Limit production of OEM spare parts

| Option | Advantages | Disadvantages |
|---|---|---|
| Limit production of OEM spare parts | Provides economic incentive to OEM to complete WFD program | Penalizes operators of low utilization airplanes that would not otherwise be affected by WFD program<br><br>Economic burden to both operators & OEMs<br><br>Parts would be sourced to other manufacturers raising bogus parts and other quality issues<br><br>Does not improve safety (airplanes of concern still operating)<br><br>Legal constraints for implementation |

## Table 10.10 – Relative Merits of Regulatory Options

Increase OEM liability for the type design

| Option | Advantages | Disadvantages |
| --- | --- | --- |
| Increase OEM liability for the type design | Economic incentive to OEM to complete WFD program | Not effective, if the OEM is not in business<br>Legal constraints for implementation<br>Does not improve safety (airplanes of concern still operating) |

## *10.3 RANKING OF APPLICABLE OPTIONS*

While all of the options considered have some merit in addressing WFD issues, some of the issues were less appropriate since they do not actually address the WFD concern. Specifically the options considering penalties against the OEM and STC Holders have no real influence in whether or not airplanes could be operated with active MSD/MED. For this reason, these options will not be considered further. The remaining options all have some considerable benefit in addressing WFD concerns and are all appropriate considering when and how they could be used. Therefore the recommendations contained herein address a suite of potential actions that regulators could use in addressing WFD concerns. These recommendations are split between short and long term actions.

The proposed regulatory options are grouped into short term and long term options, and ranked by terms of effectiveness to prevent WFD. The options also reflect regulatory actions that may be imposed.

### 10.3.1 Short Term Actions
**(Ranked in order of effectiveness)**

- Issue model specific airworthiness directives requiring inspection of design details susceptible to develop MSD/MED.
- Issue model specific airworthiness directives requiring modification or replacement of design details susceptible to develop MSD/MED.
- Issue model specific airworthiness directives establishing operating limitations.
- Issue model specific airworthiness directives establishing flight cycle service limitations.

### 10.3.2 Long Term Actions
**(Ranked in order of effectiveness)**

- Issue a FAR 121 Operating Rule and Guidance Advisory Circular for the development of model specific WFD programs.
- Issue FAR 121 Operating Rule requiring operators to revise their maintenance programs to include additional Supplemental Structural Inspection Programs.
- Issue FAR 25.1529 rule change requiring OEMs and STC Holders to develop new airworthiness limitations for WFD prone design details.

## 10.4 PROPOSAL FOR RULEMAKING

From the list above, a total of eight slightly modified proposals were considered for rulemaking.

- FAR 121 Operation Rule that set flight cycle limits for airplanes on a fleet by fleet basis unless the maintenance program at the operator is amended to include additional instructions for continued airworthiness.
- Revise FAR 25.1529 to include provision to limit the validity of the instructions for continued airworthiness for future certification programs.
- Issue Airworthiness Directives to inspect/modify structure to correct immediate safety concerns as a result of findings under either program above.
- Issue ADs to impose operational limits, where effective, to limit the possibility of failure due to WFD.
- Issue ADs to impose service limits where other remedies are not effective.
- Revoke production certificate of non-compliant OEM and STC Holders.
- Limit production of spare parts by non-compliant OEM and STC Holders.
- Increase OEM and STC Holders liability for the type design.

Of the eight, only the first five were considered appropriate for consideration.

The last three were not responsive to the safety concern and therefore not considered further. Of the first five, all five were considered to address WFD issues. The proposed recommendation for rulemaking is divided between short and long-term remedies.

### 10.4.1 Long Term Remedies

A new FAR 121 Rule that affects all existing fleets of airplanes. The rule would limit the use of the airplanes on a fleet by fleet basis unless the maintenance program at the operator is amended to include additional instructions for continued airworthiness specifically directed towards prevention and correction of widespread fatigue damage. Maintenance program modifications would include additional inspection requirements as well as references to modification requirements most likely made mandatory via ADs.

Revise FAR 25.1529 to include provision to limit the validity (in terms of flight cycles or flight hours) of the instructions for continued airworthiness. This revision would be applicable to all future certification programs. Before reaching the limit, the maintenance program would need to be re-evaluated for the possible inclusion of additional instructions for continued airworthiness. The additional instructions would be specifically directed towards prevention of widespread fatigue damage.

### 10.4.2 Short Term Remedies for Airworthiness Concerns

Issue Airworthiness Directives to inspect/modify structure to correct immediate safety concerns as a result of findings under either long-term program.

Issue ADs to impose operational limits, where effective, to limit the possibility of failure due to WFD.

Issue ADs to impose service life limits where other remedies are not effective.

### 10.4.3 Proposed 121 Rule Details

This proposed rule would be applicable to all existing fleets of airplanes certified to Part 25 or its predecessors. The rule would set a calendar time or flight cycle limit for the airplane type beyond which operation would not be allowed without FAA approved changes being made to the maintenance program for the prevention of WFD. The OEM would produce the FAA Approved changes with the assistance of both the operators and regulators. The maintenance program revisions would clearly state the limits of validity of the changes.

Maintenance program revisions would primarily be increased inspection requirements with any necessary structural modifications being mandated through ADs.

The FAR 121 (New) Rule will require an Advisory Circular.

### 10.4.4 FAR 25.1529 Rule Revision Details

This rule revision would only be applicable to new certification programs. The rule would require an OEM to declare limits of validity, in terms of flight cycles, for the structural maintenance program as part of the certification process.

Operation of the airplane would be prohibited past the stated limits without FAA Approved Changes to the maintenance program. Required changes to the maintenance program would be developed using an STG process. Program revisions for WFD would be similar to that required by the 121 Rule.

Specific immediate airworthiness concerns would be handled by AD.

The establishment of this rule revision may require an additional 121 rule to make operators comply with the limits established in the OEM maintenance program recommendations.

The FAR 25.1529 (Revised) Rule will require an Advisory Circular.

#### 10.4.5 Proposed Use of Airworthiness Directives

The proposed use of ADs is to handle specific immediate airworthiness concerns. These include but are not limited to:

- To address MSD/MED findings of inspection program implemented under the 121 (New) Rule or 25.1529 (Revised) Rule.
- To impose operational restrictions on airplanes that has exceeded the safe operational limits due to active MSD/MED in the fleet.
- To handle specific non-responsive OEMs in performing the required analysis.

### *10.5 AAWG PROPOSAL FOR RULEMAKING*

The AAWG recommendation for proposed rulemaking consists of the following proposals:

- For Existing FAR Part 25 Transport Category Airplanes - A FAA 121 (New) Rule and/or Part 39 (Amended)
- For New Certification Programs
  - FAA 25.1529 rule revision
  - FAA 121 (New) Rule for Operator Compliance
- FAA AC for Both 121 (New) and 25.1529 (Revised) Rule

Based on this proposed rulemaking Task, The AAWG further proposed language for the Terms of Reference used to initiate the Tasking for the follow-on work. The following was proposed to the Regulators and accepted for use in the Terms:

> *"ARAC is tasked to develop regulations (14 CFR part 25 and part 121 et. al) to ensure that one year after the effective date of the rule (e.g. Dec. 31, 2002), no large transport category airplane (> 75,000 lbs. Gross Take off Weight) may be operated beyond the flight cycle limits to be specified in the regulation unless an Aging Aircraft Program has been incorporated into the operators maintenance program.*
>
> *The regulations and advisory material shall establish the content of the Aging Aircraft Program. This program shall cover the necessary special inspections and modification actions for the prevention of Widespread Fatigue Damage (WFD), Structural Modifications, Supplemental Structural Inspections Programs (SSIP)/Airworthiness Limitations Instructions (ALI), Corrosion Prevention and Control Programs (CPCP) and Structural Repairs. The regulations will also require the establishment of a limit of the validity of the Aging Aircraft Program where additional reviews are necessary for continued operation."*

The full recommendation made by the AAWG to ARAC is shown in Appendix G. This proposal was submitted to ARAC on December 10, 1998. The proposal was accepted.

## 10.6 ADVANTAGES AND DISADVANTAGES

Develop FAR 121 (New) Operating Rule / FAR 25.1529 (Revised) Rule Requiring Incorporation of New Supplemental Structural Inspections and/or Modification Requirements into Operators Maintenance Program for Prevention of WFD

| Advantages | Disadvantages |
|---|---|
| Establishes service limit for maintenance programs | Service limits may be too conservative. |
| Covers all concerned fleets with a single new rule and revision to another rule. | Requires excessive time to develop, mandate and Implement, subsequent rule changes are slow. Does not affect all foreign operators. * |
| Infrastructure exists to develop model specific programs under AAWG (e.g. STG). | Requires OEM participation to develop effective large scale programs |
| Provides for operator flexibility in establishing programs for their fleets. | Requires uniform application of the rule by Individual FAA PMIs. |
| Model specific documents published by the OEM can specifically address susceptible structure. | Arbitrary compliance times to address repairs/STC changes. |
| Rule is most appropriate approach since no immediate airworthiness concern exists. | Does not address immediate airworthiness concern. Immediate concerns should be addressed by AD. |

* FAA/JAA must find way to make proposed rules effective to all operators

The operators have the following additional concerns with this regulatory proposal.

- OEM Viability / Participation in Program Development
- Technology for detection of small flaws in large area inspections
- Lead time for parts/support of the OEM
- Largely dependent on PMI for uniform enforcement
- Rule implementation times critical to prevent grounding of airplanes
- Any Additional reporting requirements/infrastructure
- Validation of OEM closing actions

# 11.0 CONCLUSIONS

The following conclusions were reached as a result of this tasking.

- With respect to the 1993 AAWG Report entitled Structural Fatigue Evaluation for Aging Airplanes
  - That the conclusions and recommendations of the 1993 AAWG Report are still generally applicable.
  - That AC 91-56A, released in April 1998 by the FAA has many inconsistencies in use of terminology and should be corrected.
  - That the list of structure susceptible to MSD/MED from the 1993 AAWG Report has been validated and expanded to include additional examples from industry experience.
  - That interaction of discrete source damage and MSD/MED need not be considered as assessment of total risk is within acceptable limits.
  - That because of the instances of MSD/MED in the fleet and the continued reliance on surveillance types of inspections to discover such damage, rules and advisory material should be developed that would provide specific programs to preclude WFD in the fleet.

- With respect to maintenance programs:
  - That an effective aging airplane program including a Mandatory Modification Program, Corrosion Prevention and Control Program, Repair Assessment Program, and a structural supplemental inspection program (SSID or ALI) is a necessary prerequisite for an effective program for MSD/MED.
  - That as long as there is an effective corrosion prevention and control program, interaction of MSD/MED with environmental degradation is minimized.
  - That the use of a Monitoring Period for the management of potential multiple site damage and multiple element damage (MSD/MED) scenarios in the fleet is possible if MSD/MED cracking is detectable before the structure loses its required residual strength.
  - That any program established to correct MSD or MED in the fleet needs careful consideration for the necessary lead times to develop resources to implement fleet action.

- That there is no universally acceptable or required damage size used for certification compliance.

- With respect to research programs:

    - That additional research into the residual strength behavior of structure with MSD/MED should be conducted to supplement existing database.
    - That the highest potential to achieve the necessary improvements of flaw detectability is seen in the field of semi-automated eddy current systems.

- With respect to the Fleet Health and MSD:

    - That every pre-amendment 45 commercial jet type airplane has had instances of MSD/MED in either test or service.
    - That normal inspections (e.g. maintenance programs plus aging airplane programs) conducted by the airlines using procedures developed by the manufacturer have found numerous instances of MSD/MED in the fleet since 1988.
    - That the value of SDRs in determining the health of the fleet with respect to MSD/MED occurrence is limited.

- With respect to Analytical Assessment of MSD/MED:

    - Sufficient technology exists to complete the audit in a conservative manner.
    - That most OEMs have voluntary WFD audit programs in progress.
    - That damage scenarios involving combinations of MSD and MED must be considered if there is a possibility of interaction.
    - That the AAWG participating manufacturers have developed different but viable means of calculating the necessary parameters to characterize MSD/MED and define appropriate maintenance actions whether it be a monitoring period or structure modification/replacement.
    - That the analysis procedures used to characterize MSD/MED scenarios on airplanes needs careful correlation with test and service evidence.

# 12.0 RECOMMENDATIONS

The following recommendations are made as a result of this study:

- That the FAA review and make changes to AC 91-56A as delineated in section 4.2.1 and 4.2.2 of this report. These changes are intended to remove ambiguous use of terminology and provide additional guidance for entities performing the structural Audit
- That the FAA fund research detailed in Section 6.0, In addition:

    - Every effort should be made to make data from tests conducted in all research programs available at the earliest possible time before formal reports are issued.
    - Tests currently funded, involving lead crack link-up, should be accomplished as soon as possible to support the first round of audits due in three years.

- That the FAA issue a subsequent tasking to ARAC to develop necessary new and/or revised certification and operational rules with advisory material to make mandatory audit requirements for MSD/MED for all transport category airplanes. This recommendation includes the development of rules and advisory material as detailed in Section 10.0.

    - Existing Transport Category Airplanes - A FAA 121 (New) Rule and/or Part 39 (Amended)
    - New Certification Programs
        - FAA 25.1529 rule revision
        - FAA 121 (New) Rule for Operator Compliance
    - FAA AC for Both 121 (New) and 25.1529 (Revised) Rule

- That WFD audits for nearly all pre-amendment 45 commercial jet airplanes should be completed and OEM documents published by December 31, 2001, with some exceptions. On other commercial jet transports, audits should be completed before the high time airplane reaches their respective design service goals.
- That a SSIP or equivalent program and Repair Assessment Program for Post Amendment 45/Pre Amendment 54 airplane be developed and implemented.
- That any rule published as a result of the subsequent tasking become effective one year after final rule publication.
- That the analysis of STCs to primary structure be held to the same audit requirements (criteria and schedule) as OEM Structure.

## *Appendix A ARAC TASKING STATEMENT*

## *PAGE: 62 FR 45690 NO. 167 08/28/97*

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# DEPARTMENT OF TRANSPORTATION

### *Federal Aviation Administration*

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine

Issues—New Task

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of a new task assignment for the Aviation Rulemaking Advisory Committee (ARAC).

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SUMMARY: Notice is given of a new task assigned to and accepted by the Aviation Rulemaking Advisory Committee (ARAC). This notice informs the public of the activities of ARAC.

FOR FURTHER INFORMATION CONTACT: Stewart R. Miller, Manager, Transport Standards Staff, ANM-110, FAA, Transport Airplane Directorate, Aircraft Certification Service, 1601 Lind Ave. SW., Renton, WA 98055-4056, telephone (425) 227-2190, fax (425) 227-1320.

# SUPPLEMENTARY INFORMATION:

## Background

The FAA has established an Aviation Rulemaking Advisory Committee to provide advice and recommendations to the FA Administrator, through the Associate Administrator for Regulation and Certification, on the full range of the FAA s rulemaking activities with respect to aviation-related issues. This includes obtaining advice and recommendations of the FAA s commitment to harmonize its Federal Aviation Regulations (FAR) and practices with the aviation authorities in Europe and Canada.

One area ARAC deals with is Transport Airplane and Engine Issues. These issues involve the airworthiness standard for transport category airplanes in 14 CFR part 25, 33, and 35 and parallel provisions in 14 CFR parts 121 and 135. The corresponding European airworthiness standards for transport category airplanes are contained in Joint Aviation Requirements (JAR)-25, JAR-E and JAR-P, respectively. The corresponding Canadian Standards are contained in Chapters 525, 533 and 535 respectively.

## The Task

This notice is to inform the public that the FAA has asked ARAC to provide advice and recommendation on the following harmonization task:

## FAR/JAR 25 Aging Aircraft

1. ARAC is tasked to review the capability of analytical methods and their validation; related research work; relevant full-scale and component fatigue test data; and tear down inspection reports, including fractographic analysis, relative to the detection of widespread fatigue damage (WFD). Since aircraft in the fleet provide important data for determining where and when WFD is occurring in the structure, ARAC will review fractographic data from representative "fleet leader" airplanes. Where sufficient relevant data for certain airplane models does not currently exist, ARAC will recommend how to obtain sufficient data from representative airplanes to determine the extent of WFD in the fleet. The review should take into account the Airworthiness Assurance Harmonization Working Group report "Structural Fatigue Evaluation for Aging Aircraft" dated October 14, 1993, and extend its applicability to all transport category airplanes having a maximum gross weight greater than 75,000 pounds.
2. ARAC will produce time standards for the initiation and completion of model specific programs (relative to the airplane's design service goal) to predict, verify and rectify widespread fatigue damage. ARAC will also recommend action that the Authorities should take if a program, for certain model airplanes, is not initiated and completed prior to those time standards. Actions that ARAC will consider include regulations to require Type Certificate holders to develop WFD programs, modification actions, operational limits, and inspection requirements to assure structural integrity of the airplanes. ARAC will provide a discussion of the relative merits of each option.
3. This task should be completed within 18 months of tasking.

## ARAC Acceptance of Task

ARAC has accepted this task and will assign it to a working group. The working group will serve as staff to ARAC to assist ARAC in the analysis of the assigned task. Working group recommendations must be reviewed and approved by ARAC. If ARAC accepts the working group s recommendations, it forwards them to the FAA and ARAC recommendations.

## Working Group Activity

The working group is expected to comply with the procedure adopted by ARAC. As part of the procedures, the working group is expected to:

1. Recommend a plan for completion of the task, including rationale, for FAA/JAA approval within six months of publication of this notice.
2. Give a detailed conceptual presentation of the proposed recommendations, prior to proceeding with its work.
3. Provide a status report at each meeting of ARAC held to consider Transport Airplane and Engine Issues.

## Participation in the Working Group

The working group will be composed of experts having an interest in the assigned task. A working group member need not be a representative of a member of the full committee.

An individual who has expertise in the subject matter and wishes to become a member of the working group should write to the person listed under the caption FOR FURTHER INFORMATION CONTACT expressing that desire, describing his or her interest in the task, and stating the expertise he or she would bring to the working group. The request will be reviewed by the assistant chair, the assistant executive director, and the working group chair and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the formation and use of ARAC are necessary and in the public interest in connection with the performance of duties imposed on the FAA by law.

Meetings of ARAC will be open to the public, except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the working group will not be open to the public, except to the extent that individuals with an interest and expertise are selection to participate. No public announcement of working group meetings will be made.

Issued in Washington, DC, on August 21, 1997.

Joseph A. Hawkins,

Executive Director, Aviation Rulemaking Advisory Committee.

[FR Doc. 97-22922 Filed 8-27-97; 8:45 am]

BILLING CODE 4910-13-M

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## Appendix B ARAC WORKING GROUP ACTIVITY REPORTS

The following pages contain the ARAC Working Group Activity Reports given to status the Tasking Activity during the eighteen months of execution.

# WORKING GROUP ACTIVITY REPORT

DATE: NOVEMBER 5, 1997

**Aviation Rulemaking Advisory Committee; Transport Airplane and Engines**

**Assigned to:** Airworthiness Assurance Working Group

**Task Title:** ANM-97-434-A - Task 5: FAR/JAR 25, Aging Aircraft

**Task Description:**

(1) Review the capability of analytical methods and their validation relative to the detection of widespread fatigue damage (WFD). Review evidence of WFD occurring in the fleet. Recommend means of collection of in-service data where data is missing. Determine extent of WFD in fleet. Extend AAWG Report on Structural Fatigue Evaluation for Aging Aircraft to be inclusive of all large transport category airplanes > 75,000 lb. GW.

(2) Establish time standards for the initiation and completion of model specific programs for prediction, verification and rectification of WFD. Recommend actions for Authorities should action not be forthcoming for certain model airplanes with discussions on the relative merits of each action proposed.

**Expected Product(s):** A task report including recommendations for FAA action.

**Schedule:**

| | Forecast Completion Date | Actual Completion Date |
|---|---|---|
| Concept Approval | 10/2/97 | 10/2/97 |
| Technical Agreement | 2/21/98 | |
| ARAC Approval for Drafting | N/A | |
| ARAC Approval for Economic/Legal Support | N/A | |
| Recommendation to ARAC | 2/21/99 | |
| Recommendation to FAA | 3/21/99 | |

**Status**: Two meetings held (9/11/97 & 10/16/97) - good progress to identify work packages and schedule issues.

**Bottlenecks:** None at this time

**Next Action:** Finish defining tasks and work packages, priorities tasks, develop schedule.

**Future Meetings:** Next meeting planned Nov. 11-12, in Atlanta. January 15, 1998 in Washington D. C.

# WORKING GROUP ACTIVITY REPORT

DATE: February 3, 1997

**Aviation Rulemaking Advisory Committee; Transport Airplane and Engines**

**Assigned to:** Airworthiness Assurance Working Group

**Task Title:** ANM-97-434-A - Task 5: FAR/JAR 25, Aging Aircraft

**Task Description:**

(1) Review the capability of analytical methods and their validation relative to the detection of widespread fatigue damage (WFD). Review evidence of WFD occurring in the fleet. Recommend means of collection of in-service data where data is missing. Determine extent of WFD in fleet. Extend AAWG Report on Structural Fatigue Evaluation for Aging Aircraft to be inclusive of all large transport category airplanes > 75,000 lb. GW.

(2) Establish time standards for the initiation and completion of model specific programs for prediction, verification and rectification of WFD. Recommend actions for Authorities should action not be forthcoming for certain model airplanes with discussions on the relative merits of each action proposed.

**Expected Product(s):** A task report including recommendations for FAA action.

**Schedule:**

| | Forecast Completion Date | Actual Completion Date |
|---|---|---|
| Concept Approval | 10/2/97 | 10/2/97 |
| Technical Agreement | 2/21/98 | |
| ARAC Approval for Drafting | N/A | |
| ARAC Approval for Economic/Legal Support | N/A | |
| Recommendation to ARAC | 2/21/99 | |
| Recommendation to FAA | 3/21/99 | |

**Status:** Four meetings held - good progress to date working Task issues everyone is cooperating

**Bottlenecks:** Issue with definitions on WFD

**Next Action:** Get Regulatory Approval of Technical Approach

**Future Meetings:** March 2-5, 1998 Gatwick UK
April 21-23, 1998 Long Beach CA
June 23-25, 1998 Hamburg GR
Aug 27-28, 1998 Williamsburg VA

***A REPORT OF THE AAWG***
***RECOMMENDATIONS FOR REGULATORY ACTION TO PREVENT WIDESPREAD FATIGUE DAMAGE IN THE COMMERCIAL AIRPLANE FLEET***

# WORKING GROUP ACTIVITY REPORT

DATE: June 10, 1998

**Aviation Rulemaking Advisory Committee; Transport Airplane and Engines**

**Assigned to:** Airworthiness Assurance Working Group

**Task Title:** ANM-97-434-A - Task 5: FAR/JAR 25, Aging Aircraft

**Task Description:**

(1) Review the capability of analytical methods and their validation relative to the detection of widespread fatigue damage (WFD). Review evidence of WFD occurring in the fleet. Recommend means of collection of in-service data where data is missing. Determine extent of WFD in fleet. Extend AAWG Report on Structural Fatigue Evaluation for Aging Aircraft to be inclusive of all large transport category airplanes > 75,000 lb. GW.

(2) Establish time standards for the initiation and completion of model specific programs for prediction, verification and rectification of WFD. Recommend actions for Authorities should action not be forthcoming for certain model airplanes with discussions on the relative merits of each action proposed.

**Expected Product(s):** A task report including recommendations for FAA action.

**Schedule:**

| | Forecast Completion Date | Actual Completion Date |
|---|---|---|
| Concept Approval | 10/2/97 | 10/2/97 |
| Technical Agreement | 2/21/98 | 3/5/98 |
| ARAC Approval for Drafting | N/A | |
| ARAC Approval for Economic/Legal Support | N/A | |
| Recommendation to ARAC | 2/21/99 | |
| Recommendation to FAA | 3/21/99 | |

**Status:** Six meetings held - Technical agreement on approach reached with Authorities Review Team (ART). Tasks adjusted appropriately. Definitions issue settled. NDI review completed.

**Bottlenecks:** None at this time except for time itself.

**Next Action:** Perform OEM Round-Robins on existing WFD methodologies.

**Future Meetings:** June 23-26, 1998 Hamburg GR.
Aug 27-28, 1998 Williamsburg VA.
Oct 6-8, 1998 Munich GR.

# WORKING GROUP ACTIVITY REPORT

DATE: September 16, 1998

**Aviation Rulemaking Advisory Committee; Transport Airplane and Engines**

**Assigned to:** Airworthiness Assurance Working Group

**Task Title:** ANM-97-434-A - Task 5: FAR/JAR 25, Aging Aircraft

**Task Description:**

(1) Review the capability of analytical methods and their validation relative to the detection of widespread fatigue damage (WFD). Review evidence of WFD occurring in the fleet. Recommend means of collection of in-service data where data is missing. Determine extent of WFD in fleet. Extend AAWG Report on Structural Fatigue Evaluation for Aging Aircraft to be inclusive of all large transport category airplanes > 75,000 lb. GW.

(2) Establish time standards for the initiation and completion of model specific programs for prediction, verification and rectification of WFD. Recommend actions for Authorities should action not be forthcoming for certain model airplanes with discussions on the relative merits of each action proposed.

**Expected Product(s):** A task report including recommendations for FAA action.

**Schedule:**

| | Forecast Completion Date | Actual Completion Date |
|---|---|---|
| Concept Approval | 10/2/97 | 10/2/97 |
| Technical Agreement | 2/21/98 | 3/5/98 |
| ARAC Approval for Drafting | N/A | |
| ARAC Approval for Economic/Legal Support | N/A | |
| Recommendation to ARAC | 2/21/99 | Partial 9/98 |
| Recommendation to FAA | 3/21/99 | |

**Status:** Eight meetings held — Consensus reached on regulatory approach, technical agreement on Monitoring Period. Industry Round Robin Started

**Bottlenecks:** None at this time except for time itself.

**Next Action:** Finish OEM Round Robins on existing WFD methodologies. Write Final Report

**Future Meetings:** Oct 7-9, 1998 Munich GR.
Dec 1-4, 1998 Seattle WA
Jan 25-29, 1999, Bristol GB.

# WORKING GROUP ACTIVITY REPORT

DATE: December 9, 1998

**Aviation Rulemaking Advisory Committee; Transport Airplane and Engines**

**Assigned to:** Airworthiness Assurance Working Group

**Task Title:** ANM-97-434-A - Task 5: FAR/JAR 25, Aging Aircraft

**Task Description:**

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**Expected Product(s):** A task report including recommendations for FAA action.

**Schedule:**

| | Forecast Completion Date | Actual Completion Date |
|---|---|---|
| Concept Approval | 10/2/97 | 10/2/97 |
| Technical Agreement | 2/21/98 | 3/5/98 |
| ARAC Approval for Drafting | N/A | |
| ARAC Approval for Economic/Legal Support | N/A | |
| Recommendation to ARAC | 3/16/99* | Partial 9/98 |
| Recommendation to FAA | 6/29/99* | |

**Status:** Ten meetings held, project on schedule for — Consensus reached on all technical issues. TOR Drafted. Final report 60% complete.

**Bottlenecks:** None at this time.

**Next Action:** Finish Final Report

**Future Meetings:** Jan 25-29, 1999, Bristol GB
March 11, 1999, Washington D.C. (AAWG TASK APPROVAL)

* DATES CHANGED TO REFLECT NORMALLY SCHEDULED TAEIG MEETING DATES

## *Appendix C MEETING VENUES*

The following meetings were significant in completing this task.

| Issues Group | Working Group | Task Group | ART Review | Meeting Date and Venue |
|---|---|---|---|---|
| X | | | | August 28, 1997, Washington D. C. |
| | X | | | September 16, 1997, Seattle WA. (BCAG) |
| | | X | | October 16, 1997, Seattle WA. (BCAG) |
| X | | | | November 5, 1997, Washington D.C. |
| | | X | | November 12-13, 1997, Atlanta GA (Lockheed-Martin) |
| | | X | | December 15-16, 1997 Toulouse France (Airbus) |
| | | X | | January 13-14, 1998, Washington D.C. (BCAG) |
| | X | | | January 15, 1998, Washington D. C. (ATA) |
| X | | | | February 15, 1998, Long Beach CA (BCAG) |
| | | X | X | March 2-5, 1998 Gatwick UK (CAA-UK/JAA) |
| | | X | | April 21-23, 1998 Long Beach CA (BCAG-LBD) |
| X | | | | June 10, 1998, Washington D. C., (AIA) |
| | | X | | June 23-26, 1998 Hamburg Germany (Daimler Benz) |
| | | X | | August 26-28, 1998 Hampton VA (BCAG) |
| | X | | | September 3, 1998, Williamsburg VA (BCAG) |
| X | | | | September 16, 1998, Seattle WA (BCAG) |
| | | X | | October 7-9, 1998 Munich Germany (IABG/Daimler Benz) |
| | | X | | December 1-4, 1998 Seattle WA (BCAG) |
| X | | | | December 10, 1998, Washington D.C. (AIA) |
| | | X | X | January 25-29, 1999 Filton UK (BAe) |
| | X | | | March 11, 1999, Washington D. C. (ATA) |
| X | | | | March 16-17, 1999, Seattle WA (BCA) |

## *Appendix D ATTENDANCE ROSTERS*

| | | TASK GROUP MEETING | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Name** | **Representing** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| Dorenda Baker | FAA | X | | | X | X | | X | | X | X | |
| Jean Yves Beaufils | Aerospatiale | | X | X | X | X | X | X | X | X | X | |
| Regis Boetsch | Airbus | X | X | X | X | X | X | X | X | X | X | X |
| John Bristow | JAA | | X | | X | | X | X | X | X | X | X |
| Aubrey Carter | Delta A/L | X | X | X | X | X | X | X | X | X | X | X |
| Richard Collins | BAe | | | X | | X | X | X | X | X | X | X |
| Dick Cummins | BAe | | X | X | X | X | | | | | | |
| Amos Hoggard | BCAG-LBD | X | X | X | X | X | X | X | X | X | X | X |
| Ed Ingram | Lockheed | | X | X | | X | X | X | X | X | X | X |
| Brian Johnson | BCAG | X | X | X | | X | X | | | | X | |
| Dave Kuchiran | Continental | X | | | X | X | | X | X | | X | X |
| Doug Marsh | BCAG | | | | X | | X | X | X | X | X | X |
| Roy Mosolf | BCAG | X | X | X | X | X | | X | X | | X | |
| Jerry Porter | Lockheed | X | X | X | X | X | X | X | X | X | X | X |
| Hans Schmidt | Daimler Benz | | X | | X | X | X | X | X | X | X | X |
| Dave Steadman | Delta A/L | | | X | X | X | X | X | X | X | X | X |
| Paul Toivonen | Lockheed | | | | | | | | X | X | X | X |
| Mark Yerger | FedEx | | | | | X | | X | | X | X | X |

## Appendix E SUPPLEMENTAL TYPE CERTIFICATES

# Summary of Federal Aviation Administration Supplemental Type Certificates

*MODIFIED TO INCLUDE ONLY MAJOR STRUCTURAL MODIFICATIONS TO PSE's. LIST IS NOT INCLUSIVE OF ALL STRUCTURAL STCs AND DOES NOT INCLUDE THOSE STCs ACCOMPLISHED ON ONLY ONE AIRPLANE*

**JANUARY 1998**

## Airbus Industrie

| AIRCRAFT MAKE MODEL & T.C. NO. | STC NO. | DESCRIPTION | ACO | STC HOLDER |
|---|---|---|---|---|
| A300B4-103, -203; *T.C. A35EU* | ST00445SE | Conversion of passenger airplane to haul cargo on main deck. Amended 8/29/97. | NM-S | Flight Structures, Inc. 4407 172nd Street NE Arlington WA 98223 |
| A310-203 (Basic, Variant 01, and Variant 04); A310-221(Basic, Variant 01, and Variant 04), A310-220 (Variant 01 and Variant 04), A310-222 (Variant 01 and Variant 04); *T.C. A35EU* | ST00100NY | Conversion of Passenger to Freighter configuration by installing a large Main Deck Cargo door, upper deck class "E" cargo compartment, floor reinforcement, and other associated modifications. Amended 6/12/96. | NE-NY | Daimler-Benz Aerospace Airbus Kreetslag 10 PO Box 95 01 09 D-21111 Hamburg Germany |

## British Aerospace

(See Raytheon Corporate Jets and Jetstream for other British Aerospace models)

| AIRCRAFT MAKE MODEL & T.C. NO. | STC NO. | DESCRIPTION | ACO | STC HOLDER |
|---|---|---|---|---|
| BAe.146-200A; *T.C. A49EU* | SA1970SO | Installation of aft cargo door Reissued 10/17/88. | CE-A | Pemco Aeroplex, Inc. P.O. Box 929 Dothan, AL 36302-0929 |
| BAC 1-11; *T.C. A5EU* | SA1350SW | Installation of center wing tank fuel system. Reissued 5/30/79. | WE | Tiger Air Svc Center Inc 3000 North Clybourn Ave Burbank, CA 91505 |
| BAC 1-11 400 Series equipped with Rolls Royce RB163-25 Spey51-14 engines; *T.C. A5EU* | ST846SO | Increase maximum ramp weight to89,000 lbs., increase maximum take- off weight to 88,500 lbs. and decrease maximum landing weight to 77,200 lbs. Issued 7/1/75. | SO | Bruce Gilman P.O. Box 1372 Vicksburg, MS 39180 |

| | | | | |
|---|---|---|---|---|
| BAC 1-11, 200, 400 Series; 401AK, 410AQ, 419EP, 412A/EB; *T.C. A5EU* | SA2813WE | Structural modifications per FAA sealed American Co. top Dwg. BAC1100 necessary to allow operation at the increased takeoff weight of 88,500 lbs. Reissued 3/28/84. | NM | Tigerair, Inc. 1888 Century Park East Los Angeles, CA 90067 |

# BOEING AIRPLANE COMPANY

| AIRCRAFT MAKE MODEL & T.C. NO. | STC NO. | DESCRIPTION | ACO | STC HOLDER |
|---|---|---|---|---|
| 707-100B; *T.C. 4A21* | SA984CE-D | Increase maximum zero fuel weight. Issued 9/22/76. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 707-100B; *T.C. 4A21* | SA2686SO | Installation of Hush Kits. Issued 1/23/90. | CE-A | Quiet Nacelle Corp. 8000 N.W. 56th St. Miami, FL 33266 |
| 707-100B; *T.C. 4A21* | SA3595NM | Modification of the Boeing 707-100B airplanes. Reissued 3/29/96. | NM-L | Omega Aviation Serv. 5/6 Knockbeg Point Shannon Airport Co. Clare Ireland |
| 707-123B; *T.C. 4A21* | SA983CE-D | Cargo door and interior installation non-convertible air freighter. Issued 5/24/76. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 707-131; *T.C. 4A21* | SA862CE | Addition of large cargo door in left hand side of fuselage. Issued August 1972. | CE | The Boeing Co 3801 S. Oliver Wichita, KS 67210 |
| 707-227; *T.C. 4A21* | SA781SO | Installation of a cargo loading door. Reissued 2/8/96. | CE-A | Pemco Aeroplex, Inc. 1943 50th Street North Birmingham AL 35212 |
| 707-300; *T.C. 4A26* | SA5503NM | Installation of a number two left hand entry door. Amended 5/22/92. | WE | Transport Aircraft Technical Services Co. 2977 Radondo Ave., Suite B Long Beach, CA 90806- |
| 707-300B Advanced, -300C; *T.C. 4A26* | SA2685SO | Installation of Hush Kits. Issued 12/22/89. | CE-A | Quiet Nacelle Corp. 8000 N.W. 56th St. Miami, FL 33166 |
| 707-300B (Advanced), -300C; *T.C. 4A26* | SA2699NM | Modification of the Boeing Model 707-300B (advanced) and 707-300C airplanes. Reissued 8/14/91. | NM-L | Lucas Aviation Inc. 495 South Fairview Santa Barbara, CA 93117 |
| 707-300B (Advanced), 707-300C; *T.C. 4A26* | SA4782NM | Installation of engine hush kits. Issued 11/2/89. | NM | Shannon Engr.Inc. 7675 Perimeter Rd. South, Suite 200 Seattle, WA 98108 |

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|---|---|---|---|---|
| 707-321; *T.C. 4A26* | SA778CE | Addition of large cargo door in left hand side of fuselage. Issued June 1971. | CE | The Boeing Co 3801 S. Oliver Wichita, KS 67210 |
| 707-321, -321B, -321C, -331, -386C; *T.C. 4A26* | ST652SO-D | Installation of P&W JT8D engine and associated structural and fairing pod under L.H. wing between No. 2 engine and fuselage. Reissued 9/7/78. | EA | Pan American World Airways, Inc. JFK Int'l Airport Jamaica, NY 11430 |
| 707-323C; *T.C. 4A26* | SA2401WE | Alter type design by installation of Transequip structural igloo assembly P/N 245084 in conjunction with loading systems 65-42625, 65-42630, 65-44166, and 65-34899. Reissued 4/28/93. | NM-L | Air Cargo Equipment 2930 East Maria St Rancho Dominquez, CA 90221 |
| 707-331; *T.C. 4A26* | SA854CE-D | 60,000 lbs. main deck allowable loading. Issued 12/7/73. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 707-387B; *T.C. 4A26* | SA1232CE-D | Installation of large cargo door in left hand side of forward fuselage. Issued 6/10/77. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 707-387B; *T.C. 4A26* | SA1233CE-D | Increase maximum zero fuel weight to 96,162 KG Issued 8/31/77. | CE | The Boeing Co 3801 S. Oliver Wichita, KS 67210 |
| 720 Series; *T.C. 4A28* | SA848CE-D | Additional overwing escape hatch installation interior configuration 2nd additional overwing escape hatch installation. Issued July 1975. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 720B; *T.C. 4A2* | SA2687SO | Installation of Hush Kits. Issued 1/23/90. | CE-A | Quiet Nacelle Corp 8000 N.W. 56th St. Miami, FL 33166 |
| 720-023B; *T.C. 4A28* | SA985CE-D | Side cargo door and interior installation. Issued 3/17/77. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 720-023B, -030B, 720-047B; *T.C. 4A28* | SA851CE-D | Increase maximum ramp weight to 235,000 lbs. and zero fuel WEight to 156,000 lbs. Amended 11/21/78. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 727; *T.C. A3WE* | ST01043AT | Approval of increased operating weights as substantiated by design data listed in SIE master reports. Issued 5/21/96. | CE-A | Structural Integrity Engr 6512 Hollywood Blvd Hollywood FL 33024 |
| 727 Series, 727-100 Series; *T.C. A3WE* | SA1368SO | Installation of a cargo door. Amended 8/6/85. | CE-A | Aeronautical Engrs. P.O. Box 661027 Miami, FL 33166 |
| 727 Series, 727-100 Series, 727-200 Series; *T.C. A3WE* | SA1797SO | Installation of a cargo door. Amended 4/7/93. | CE-A | Aeronautical Engrs. P.O. Box 661027 Miami, FL 33166 |

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|---|---|---|---|---|
| 727-46; *T.C. A3WE* | SA847CE-D | Structural and system modification for installation of service door and retractable step. Issued July 1975. | CE | The Boeing Co 3801 South Oliver Wichita, KS 67210 |
| 727-100 Series; *T.C. A3WE* | SA1444SO | Installation of a cargo door, cargo interior, and 9G restraint net. Reissued 9/5/90. | CE | Pemco Aeroplex, Inc. P.O. Box 2287 Birmingham, AL 35201 |
| 727-100 Series; *T.C. A3WE* | SA1896SO | Installation of a cargo door and associated class "E" cargo compartment. Reissued 2/8/96. | CE-A | Pemco Aeroplex 1943 50th St North Birmingham AL 35212 |
| 727-100; *T.C. A3WE* | SA4912NM | Increase in the maximum zero fuel weight. Issued 3/27/90. | NM | Leth and Associates 85 222nd Place SE Redmond, WA 98052 |
| 727-100; *T.C. A3WE* | SA5767NM | Increase in zero fuel weight. Issued 10/1/92. | NM-S | The Carstan Corp Aeronautical Engineering Svc. 4600 Kietzke Lane Building F, Suite 155 Reno, NV 89502 |
| 727-100; *T.C. A3WE* | SA5768NM | Increase in the maximum taxi and flight WEights. Issued 10/1/92 . | NM-S | The Carstan Corp Aeronautical Engineering Svc. 4600 Kietzke Lane Building F, Suite 155 Reno, NV 89502 |
| 727-100; *T.C. A3WE* | SA5769NM | Increase in the maximum taxi and flight weights. Issued 10/1/92 . | NM-S | The Carstan Corp Aeronautical Engineering Svc. 4600 Kietzke Lane Building F, Suite 155 Reno, NV 89502 |
| 727-100 (S/N 19183 only); *T.C. A3WE* | ST00782AT | Approval of maximum zero fuel weight increase to 132,000 pounds as substantiated by the design data. Issued 6/8/95. | CE-A | Structural Integrity Engr 6512 Hollywood Blvd Hollywood FL 33024 |
| 727-100, -200; *T.C. A3WE* 35201 | SA1509SO | Installation of a cargo door. Amended 8/31/95. | CE-A | Pemco Aeroplex, Inc. P.O. Box 2287 Birmingham, AL |
| 727-100, -200; *T.C. A3WE* | SA1767SO | Installation of a cargo door. Amended 2/12/88. | CE-A | Hayes Int'l Corp. P.O. Box 929 Dothan, AL 36302 |
| 727-100, -200; *T.C. A3WE* | SA7447SW | 727-100 modification from an eight unit load device to a nine unit load device configuration. 727-200 modification from an eleven unit load device to a twelve unit load device. Reissued 8/1/91. | CE-A | Federal Express 3101 Tchulahoma Memphis, TN 38118 |

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|---|---|---|---|---|
| 727-100, -200; *T.C. A3WE* | SA7681SW | Fuselage access door. Issued 12/7/89. | SW | Dalfort Corp. 7701 Lemmon Ave. Dallas, TX 75209 |
| 727-100/-200; *T.C. A3WE* | ST00621AT | Installation of aft engine mount on engines 1 and 3. Issued 12/13/94. | CE-A | Flight Structures, Inc. 18810 59th Avenue NE Arlington WA 98223 |
| 727-200 Series; *T.C. A3WE* | ST00015AT | Installation of cargo door, Class "E" cargo compartment interior, cargo handling system and barrier bulkhead. Amended 3/20/96. | CE-A | ATAZ, Inc. P O Box 521477 Miami FL 33125 |
| 727-200; *T.C. A3WE* | SA5854NM | Modification of the B727 airplane by installation of cascade thrust reversers, acoustic spacers and acoustic tailpipes. Issued 11/20/92. | NM-L | Aviation Equipment, Inc. 7230 Fulton Avenue North Hollywood, CA 91605 |
| All Models of 727, 727-100, 727C, 727-100C, 727-200, 727-200F; *T.C. A3WE* | SA5938NM | Installation of winglets, associated changes in flap and aileron positions and rigging, and related changes to the navigation beacons. Reissued 3/30/95. | NM-S | Winglet Systems, Inc. |
| 727-200; *T.C. A3WE* | SA5960NM | Increase in maximum zero fuel weight. Issued 5/21/93. | NM-L | The Carstan Corp 111 N. First Street, Suite 301 Burbank, CA 91502 |
| 727-200; *T.C. A3WE* | SA4833NM | Installation of engine inlet and exhaust noise attenuation treatment including incorporation of exhaust gas internal mixers and modifications to the engine thrust reversers. Amended 7/25/95. | NM-L | Federal Express Corp. 3101 Tchulahoma Memphis, TN 38228 |
| 727-200; *T.C. A3WE* | SA5961NM | Increase in the maximum taxi and flight weights. Issued 5/21/93. | NM-L | The Carstan Corporation 111 N. First St, Suite 301 Burbank, CA 91502 |
| 727-200; *T.C. A3WE* | ST00350AT | Installation of engine nacelles with noise suppression modifications. Issued 10/4/93. | CE-A | Federal Express Corp P.O. Box 727 Memphis, TN 38194 |
| 727-200; *T.C. A3WE* | ST00076SE | Increase in maximum zero fuel weight to 152,000 lbs. and increase in maximum landing weight up to 161,000 lbs. Amended 7/19/95. | NM-L | Altair Holdings Ltd. 111 N. First Street, Suite 301 Burbank, CA 91502 |
| 727-200; *T.C. A3WE* | ST00077SE | Increase in maximum taxi and flight weights to 191,000 and 189,500 lbs. Issued 4/13/94. | NM-L | Altair Holdings Ltd. 111 N First Street, Suite 301 Burbank, CA 91502 |
| 727-200; *T.C. A3WE* | ST00094SE-T | Increase in the maximum zero fuel weight. Issued 5/31/94. | NM-S | Leth & Associates 85 222nd Place S.E. Redmond, WA 98052 |

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|---|---|---|---|---|
| 727-200; *T.C. A3WE* | ST00106SE | Increase in the maximum zero fuel weight to 144,000 lbs. Issued 8/11/94. | NM-SE | Altair Holdings Ltd. 111 N. First Street, Suite 301 Burbank CA 91502 |
| 727-200; *T.C. A3WE* | ST00107SE | Increase in the maximum taxi and flight weights up to 183,000 and 182,500 lbs . Issued 8/11/94. | NM-SE | Altair Holdings Ltd. 111 N. First Street, Suite 301 Burbank CA 91502 |
| 727-200; *T.C. A3WE* | ST00116SE | Increase in the maximum taxi and flight weights up to 197,700 and 196,000 lbs. Amended 6/14/95. | NM-SE | Altair Holdings Ltd. 111 N First Street, Suite 301 Burbank, CA 91502 |
| 727-200; *T.C. A3WE* | ST00117SE | Increase in the maximum zero fuel weight to 155,000 lbs. Amended 10/25/95. | NM-SE | Altair Holdings Ltd. 111 N First Street, Suite 301 Burbank, CA 91502 |
| 727-200 (S/N s 21157, 21158, 22476, 22549 only); *T.C. A3WE* | ST00925AT | Approval of increased operating weights as substantiated by the design data listed in SIE No. SIE-28-707. Amended 12/21/95. | CE-A | Structural Integrity Engr 6512 Hollywood Boulevard Hollywood FL 33024 |
| 727-200, S/N s 21085, 20997 only; *T.C. A3WE* | ST00926AT | Approval of increased operating weights as substantiated by the design data listed in SIE No. SIE-28-713. Issued 12/5/95. | CE-A | Structural Integrity Engr 6512 Hollywood Boulevard Hollywood FL 33024 |
| 727-200 (S/N 21269, 21245 only); *T.C. A3WE* | ST00901AT | Approval of increased operating weights as as substantiated by the design data listed in SIE-28-902. Amended 12/21/95. | CE-A | Structural Integrity Engr 6512 Hollywood Blvd Hollywood FL 33024 |
| 727-200 Series; *T.C. A3WE* | ST00106SE | Increase in maximum zero fuel weights to 144,000 lbs., and increase in maximum landing weight to 145,500 lbs. Amended 9/11/97. | NM-S | Altair Holdings, Ltd. 111 N First Street, Suite 301 Burbank CA 91502 |
| 727-200 (S/N 19483, 19484, 19486, 19491, 20180, 20184, 20185, 20187, 20995, 20996 19480, 19492, 19481, 19482, 19485, 20191 only); T.C. A3WE | ST00633AT | Approval of maximum zero fuel weight increase from 138,000 pounds to 146,000 pounds. Amended 7/12/95. | CE-A | Structural Integrity Engr 6512 Hollywood Blvd Hollywood FL 33024 |
| 727-200, S/N 21930 and 21931 only; *T.C. A3WE* | ST00671AT | Approval of maximum landing weight increase from 160,000 pounds to 164,000 pounds. Issued 3/1/95. | CE-A | Structural Integrity Engr 6512 Hollywood Blvd Hollywood FL 33024 |
| 727-200; *T.C. A3WE* | ST00719AT | Approval of increased operating weights. Amended & Reissued 8/28/96. | CE-A | Structural Integrity Engr 9560 Topanga Canyon Bvld Chatsworth, CA 91311 |

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|---|---|---|---|---|
| 727-200 (S/N 22080 only); *T.C. A3WE* | ST00720AT | Approval of maximum zero fuel weight and maximum landing weight (Flaps 30) increases to 157,500 pounds and 166,000 pounds, respectively. Issued 3/28/95. | CE-A | Structural Integrity Engr 6512 Hollywood Blvd Hollywood FL 33024 |
| 727-200 (S/N 20938 only); *T.C. A3WE* | ST00795AT | Approval of maximum zero fuel weight increase (155,000 lbs.) and maximum landing weight increase (164 lbs.). Amended 7/12/95. | CE-A | Pemco Aeroplex, Inc. 1943 50th Street North Birmingham AL 35212 |
| 727-200; *T.C. A3WE* | ST00939AT | Approval of increased operating weights as substantiated by the design data listed in SIE Master Report List SIE 28-706, Revision A. Amended 8/28/96. | CE-A | Structural Integrity Engr 9560 Topanga Canyon Blvd Chatsworth, CA 91311 |
| 727-200 (S/N 21161 only); *T.C. A3WE* | ST00949AT | Approval of increased operating weights as substantiated by the design data listed in SIE Master Report List SIE-28-717. Issued 1/22/96. | CE-A | Structural Integrity Engr 6512 Hollywod Blvd Hollywood FL 33024 |
| 727-200 (S/N s 21327, 21328, 21329, 21330, 21331 only); *T.C. A3WE* | ST01013AT | Approval of increased operating weights as substantiated by the design data listed in SIE report SIE-33-701. Issued 4/15/96. | CE-A | Structural Integrity Engr 6512 Hollywood Blvd Hollywood FL 33024 |
| 727-222; *T.C. A3WE* | SA4063WE | Deletion of the pair of excess Type I emergency exits located at station 720 and 15. Issued 11/29/79. | NM-L | United Airlines, Inc. San Francisco Int'l Arpt San Francisco, CA 94128 |
| 737-100, -200, -200C Series; *T.C. A16WE* | ST223CH | Installation of a Stage 3 hushkit when powered by P&W JT8D-9 series engines. Amended 5/30/95. | CE-C | AvAero 400 N. Beechgrove Rd. Wilmington, OH 45177 |
| 737-100 Series, 737-200 Series; *T.C. A16WE* | ST00287AT | Installation of a cargo door. Issued 7/27/93. | CE-A | Aeronautical Engineers, P.O. Box 661027 Miami, Fl 33166 |
| 737-200, S/N's 20549, 22002, 22540; *T.C. A16WE* | ST00604AT | Approval of maximum zero fuel weight increase. Issued 11/18/94. | CE-A | Pemco Aeroplex, Inc. 1943 50th Street North Birmingham, AL 35212 |
| 737-200, -300 Series; *T.C. A16WE* | SA2969SO | Installation of a cargo door. Amended 2/17/94. | CE-A | Pemco Aeroplex, Inc. P.O. Box 2287 Birmingham, AL 35201 |
| 747-2B5B; *T.C. A20WE* | SA2123CE-D | Conversion of passenger airplane to main deck side cargo door dedicated special freighter. Amended 5/19/92. | CE-W | Boeing Commerical Airplane Group, Wichita Division P.O. Box 7730 Wichita, KS 67277-7730 |
| 747-100; *T.C. A20WE* | SA2322SO | Installation of a cargo door. Reissued 8/8/91 | CE-A | GATX/Airlog Company P.O. Box 3529 Albany, GA 31706 |

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| 747-100;<br>*T.C. A20WE* | SA5199NM | Increase maximum zero fuel Weight.<br>Reissued 12/19/91. | NM-S GATX/Airlog<br>3303 N. Sheridan<br>Gate 32, Hangar 19<br>Tulsa, OK. 74115 |
| 747-100 Series,<br>747-200 Series;<br>*T.C. A20WE* | SA976CE-D | Fuselage structure and related modification for cargo.<br>Amended 10/28/77. | CE The Boeing Wichita Co.<br>3801 South Oliver<br>Wichita, KS 67210 |
| 747-122;<br>*T.C. A20WE* | SA4224NM-D | Structural modification to stretched aft upper deck.<br>Reissued 3/17/95. | NM-L GATX/Airlog<br>P O Box 3529<br>Albany GA 31706 |
| 747-200;<br>*T.C. A20WE* | SA1767SO | Installation of cargo door.<br>Issued 3/25/85. | CE-A Hayes International Corp.<br>P.O. Box 929<br>Dothan, AL 36302 |
| 747-200;<br>*T.C. A20WE* | SA5759NM | Increase maximum zero fuel Weight.<br>Amended 4/27/95. | NM-S Gatx/Airlog Company<br>3303 N. Sheridan Road<br>Tulsa, OK 74115 |
| 747-200B Series;<br>*T.C. A20WE* | SA4227NM-D | Conversion of a passenger airplane to a freighter configuration with a side-cargo door.<br>Reissued 5/3/95. | NM-L GATX/Airlog<br>P O Box 3529<br>Albany GA 31706 |
| 747-200B;<br>*T.C. A20WE*<br>Motte St. | ST00380SE | Increase in the maximum zero fuel weight to 590,000 lb.<br>Issued 10/31/96. | NM-S Becontree Holdings Limited<br>La Motte Chambers, La<br>St. Helier, Jersey JE1 1BJ<br>Channel Islands |
| 747-206B;<br>*T.C. A20WE* | SA1442CE-D | Installation of Type I door, left side, upper deck fuselage.<br>Issued 10/25/79. | CE-C Boeing Wichita Company<br>3801 South Oliver<br>Wichita, KS 67210 |
| 747-237B;<br>*T.C. A20WE* | SA1444CE-D | Installation of type I door (left side, upper deck fuselage) extinsion of upper deck and interior reconfiguration.<br>Issued 7/25/80. | CE Boeing Military<br>Airplane Company<br>3801 South Oilver<br>Wichita, KS 67210 |
| 747-267B;<br>*T.C. A20WE* | SA2725CE-D | Conversion of passenger airplane to main deck side cargo door dedicated special freighter.<br>Issued 7/30/92. | CE-W Boeing Commercial Aiplane<br>Group, Wichita Div.<br>P.O. Box 7730<br>Wichita, KS 67277-7730 |
| 747-2D3BC;<br>*T.C. A20WE* | SA2727CE-D | Conversion of a combi airplane to main deck side cargo door dedicated special freighter.<br>Issued 10/14/92. | CE-W Boeing Commercial Airplane<br>Group, Wichita Division<br>P.O. Box 7730<br>Wichita, KS 67277-7730 |

# Lockheed Aircraft

| AIRCRAFT MAKE MODEL & T.C. NO. | STC NO. | DESCRIPTION | ACO | STC HOLDER |
|---|---|---|---|---|
| 188A; *T.C. 4A22* | SA1064SO | Increase in zero fuel weight from 82,500 lbs. to 90,800 lbs. Issued 4/13/79. | SO | Aeronautical Engrs. Inc. P.O. Box 661087 Miami, FL 33166 |
| 188A; *T.C. 4A22* | SA1071SO | Increase in zero fuel weight from 86,000 pounds to 92,340 pounds. Issued 6/14/79. | SO | Aeronautical Engrs. Inc. P.O. Box 661087 Miami, FL 33166 |
| 188A; *T.C. 4A22* | SA2536WE | Modification and installation of: aft cargo door; cargo loading and retention system; strengthened floor support structure; increased zero fuel weight to 90,000 pounds; improved avionics and instrumentation. Amended 7/24/75. | WE | Lockheed Acft Svc Co. Burbank, CA 91500 |
| 188A, 188C; *T.C. 4A22* | SA533GL | Install a smoke elimination door. Issued 6/16/81. | GL | Zantop Int'l Airlines Inc Detroit - Willow Run Arpt Ypsilanti, MI 48197 |
| 188A, 188C; *T.C. 4A22* | ST852SO | Installation of cargo door. Issued 9/25/75. | SO | Aeronautical Engrs. Inc. P.O. Box 480602 Miami, FL 33148 |
| 188A, 188C; *T.C. 4A22* | SA1754WE | Installation of cargo doors, cargo floor and other changes. Amended 1/22/74. | WE | Lockheed Acft Svc Co. P.O. Box 33 Ontario Int'l Airport Ontario, CA 91761 |
| 188A (S/N 1035 and up), 188C; *T.C. 4A22* | SA2889WE | Conversion of Lockheed Model 188A and 188C into all cargo configuration by installation of cargo door, cargo floor and cargo lining. Amended 8/25/75. | WE | American Jet Ind Inc. 7701 Woodley Avenue Van Nuys, CA 91406 |
| 188A (S/N 1035 and up), 188C; *T.C. 4A22* | SA2963WE | Increase maximum zero fuel weight to 90,000 pounds by modifying aircraft. Issued 1/29/75. | WE | American Jet Ind Inc. 7701 Woodley Avenue Van Nuys, CA 91406 |
| 188A (S/N 1035 and up), 188C; *T.C. 4A22* | SA3059WE | Maximum landing weight substantiated to 98,102 pounds (from 95,650 pounds). Issued 10/23/75. | WE | American Jet Industries 7701 Woodley Avenue Van Nuys, CA 91406 |
| 188A (S/N 1035 and up), 188C; *T.C. 4A22* | SA3098WE | Structural modifications. Issued 10/31/75. | WE | American Jet Industries 7701 Woodley Avenue Van Nuys, CA 91406 |
| 188A, 188C; *T.C. 4A22* | SA3152WE | Installation of cargo door only. Issued 4/29/76. | WE | American Jet Ind Inc. 7701 Woodley Avenue Van Nuys, CA 91406 |
| 188A (S/N 1035 and up), 188C; *T.C. 4A22* | SA3159WE | Installation of cargo floor and interior. Issued 4/29/76. | WE | American Jet Ind Inc. 7701 Woodley Avenue Van Nuys, CA 91406 |

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| 188A, 188C; *T.C. 4A22* | SA5502NM | Modification of Lockheed model L-188A/L-188C airplanes. Reissued 3/20/92. | NM-L | Channel Express (Air Serviced) Ltd. Building 470 Bournamouth International Christ Church, Dorset BH236DL United Kingdom |
| 188C; *T.C. 4A22* | SA707EA | Relocation of cabin window right-side from fuselage station 217-236 to fuselage station 333-352. Reissued 3/20/74. | WE | Lockheed Acft Svc Co. P.O. Box 33 Ontario, CA 91761. |
| 188C; *T.C. 4A22* | SA708EA | Installation of opening in fuselage right hand for emergency exit between fuselage station 226 and fuselage station 253.4. Reissued 3/20/74. | WE | Lockheed Acft Svc Co. P.O. Box 33 Ontario, CA 91761 |
| 188C; *T.C. 4A22* | SA709EA | Installation of floor structure and miscellaneous modifications. Reissued 3/20/74. | WE | Lockheed Acft Svc Co. P.O. Box 33 Ontario, CA 91761 |
| 188C; *T.C. 4A22* | SA1081SO | Increase in fuel weight from 86,000 pounds to 92,340 pounds. Amended 7/6/95. | CE-A | Aeronautical Engrs. Inc. 7765 NW 54th Street Miami, FL 33166 |
| 188C; *T.C. 4A22* | SA1637WE | Installation of cargo door approximately 80 inches high by 144 inches long in left side of fuselage forebody. | WE | Lockheed Acft Svc Co. P.O. Box 33 Ontario, CA 91764 |
| L-188C; *T.C. 4A22* 0460 | SA1833SO | Installation of an aft cargo door and cargo compartment interior. Reissued 8/7/91. | CE-A | Universal Cargo Doors and Services, Inc. P.O. Box 660460 Miami Springs, FL 33166- |
| L-188C; *T.C. 4A22* 0460 | SA1834SO | Installation of a forward cargo door and cargo compartment interior. Reissued 8/7/91. | CE-A | Universal Cargo Doors and Services, Inc. P.O. Box 660460 Miami Springs, FL 33166- |
| 188C; *T.C. 4A22* | SA2694WE | Modification for installation of: nose and wingtip instrumentation boom provisions; research apparatus mounting provisions; dropsonde dispenser; increased breathing oxygen provisions and research electrical system. Issued 5/30/73. | RM | University Corp. for Atmospheric Research P.O. Box 1470 Boulder, CO 80302 |
| 188C; *T.C. 4A22* | SA2695WE | Modification for installation of: nose instrumentation boom and wingtip instrumentation boom. Modification per STC SA2694WE is required prior to this modification. Issued 5/30/73. | RM | University Corp. for Atmospheric Research P.O. Box 1470 Boulder, CO 80302 |

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| L-1011-1-15; Corporation *T.C. A23WE* | SA8011NM | Modification to include provisions only for carriage and launch of Pegasus SIV satellite insertion vehicle (SIV). Reissued 6/22/95. | NM-L | Orbital Sciences 1301 Skyway Drive Bakersfield, CA 93398 |
| L-1011-385-1; *T.C. A23WE* | SA2108SO | Installation of a forward cargo door. Reissued 9/14/95. | CE-A | Avtec STC AG Dufourstrasse 5. CH4052 Basel Switzerland |
| L-1011-385-1; *T.C. A23WE* | ST00259AT | Increase maximum takeoff weight to 450,000 lbs. Issued 6/18/93. | CE-A | Argosy International 6101 Blue Lagoon Dr, Ste 440 Miami, FL 33126 |
| L-1011-385-1; *T.C. A23WE* | ST00591AT | Increase maximum takeoff weight to 450,00 lbs. Reissued 12/6/94. | CE-A | Argosy International 6303 Blue Lagoon Dr., Ste 364 Miami FL 33126 |
| L-1011-385-1-15; *T.C. A23WE* | ST00847AT | Installation of main deck cargo door, main deck floor modification/ cargo handling and restraint system, 9g cargo bulkhead, Class E cargo compartment and courier seating (with lavatory/galley storage and crew bunks). Amended 12/20/95. | CE-A | Newport Aeronautical 1785 Sahara, Suite 490 Las Vegas NV 89104 |
| L-1011-385-1-15; *T.C. A23WE* | ST01103AT | Increase in Maximum Design Landing Weight from 368,000 lbs. to 38,000 lbs. Issued 8/5/96. | CE-A | Newport Aeronautical 1785 E. Sahara / Suite 490 Las Vegas, NV 89104 |

# McDonnell Douglas Corporation

| AIRCRAFT MAKE MODEL & T.C. NO. | STC NO. | DESCRIPTION | ACO | STC HOLDER |
|---|---|---|---|---|
| DC-8-21, -31, -32, -33, -41, -42, -43, -51, -52, -53, -55, -61, -62, -63, -71, -72, -73; T.C. 4A25 | SA1063SO | Installation of forward cargo door. Amended 7/14/94. | CE-A | Aeronautical Engrs. Inc. 7301 NW 32nd Avenue Miami, FL 33147 |
| DC-8-21; *T.C. 4A25* | SA3869WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 2/20/79. | WE | G. S. Rasmussen P. O. Box 10519 Glendale, CA 91209 |
| DC-8-21 (S/N's 45422-45427, 45429-45431, 45433-45437 only), DC-8-32, -33, 51 (S/N 45648 only); *T.C. 4A25* | SA421NW | Removal of passenger confirmation interior items and installation of a cargo door on the forward left hand side of the fuselage, cargo restraint bulkhead at station 300, heavy duty flooring, class "E" cargo compartment, and provisions for two (2) additional crew members. Reissued 6/28/88. | CE-A | Rosenbalm Aviation, Inc. (RAI) P.O. Box 10136 Macon, GA 31297 |
| DC-8-21, -31, -32, -51, -52, -53, -55, -61, -62, -63; T.C. 4A25 | SA1862SO | Installation of a cargo door. Amended 5/4/94. | CE-A | Agro Air Associates, Inc. P.O. Box 524236 Miami, FL 33152 |
| DC-8-33, S/N's 45261, 45377, 45388, 45421, 45626 only; *T.C. 4A25* | SA260NW | Removal of passenger configuration interior items and installation of a cargo door on the forward left hand side of the fuselage, cargo restraint bulkhead at Station 300, heavy-duty flooring, Class "E" cargo compartment, and provisions for two (2) additional crew members. Reissued 2/9/89. | NW | Rosenbalm Aviation P.O. Box 1524 Medford, OR 97501 |
| DC-8-33; *T.C. 4A25* | SA3403WE | Conversion of passenger airplane to cargo only configuration by installation of cargo door, cargo handling system, and increasing maximum landing and zero fuel weight. Amended 6/14/78. | WE | McDonnell Douglas Corp. 3855 Lakewood Blvd Long Beach, CA 90846 |
| DC-8-33; *T.C. 4A25* | SA3611WE | Modification to permit increase in maximum allowable zero fuel weight. Issued 3/27/78. | WE | G.S. Rasmussen P.O. Box 2052 Glendale, CA 91209 |
| DC-8-33; *T.C. 4A25* | SA3804WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 12/13/78. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |

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| DC-8-33; *T.C. 4A25* | SA3907WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 4/20/78. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-33; *T.C. 4A25* | SA3910WE | Modifications to permit an increase in maximum allowable zero fuel weight. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-33, -43, 61F, 62F, 63F, 71F, 72F, 73F, DC-8F-54, -55; *T.C. 4A25* | SA1703GL | Modify existing cargo door assembly by incorporating a window doubler assembly thereby converting cargo door from a no window configuration to a configuration having one window. Issued 2/2/192. | CE-C | National Aircraft Service, 4332 Macon Road Tecumseh, MI 49286 |
| DC-8-43; *T.C. 4A25* | SA3612WE | Modifications to permit increase in maximum allowable zero fuel weight. Issued 3/27/78. | WE | G.S. Rasmussen P.O. Box 2052 Glendale, CA 91209 |
| DC-8-43; *T.C. 4A25* | SA3749WE | Conversion of passenger airplane to cargo only configuration by installation of cargo door, cargo floor, and increasing maximum landing and zero fuel weight. Issued 9/28/78. | WE | McDonnell Douglas Corp. 3855 Lakewood Blvd Long Beach, CA 90846 |
| DC-8-43; *T.C. 4A25* | SA3805WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 12/26/78. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-43; *T.C. 4A25* | SA3880WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 3/28/79. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-43; *T.C. 4A25* | SA3911WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 4/23/79. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-51; *T.C. 4A25* | SA4078WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 2/6/80. | WE | G. S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-51; *T.C. 4A25* | SA4080WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 8/21/80. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-51, S/N 45855 only; *T.C. 4A25* | ST00543AT | Increase in aircraft operating weights (Maximum takeoff weight - 315,000 lbs., maximum landing weight - 217,000 lbs., maximum zero fuel weight - 203,000 lbs.) Issued 7/20/94. | CE-A | Aircraft Modification Design 8960 Ridgemond Drive Atlanta, GA 30350 |
| DC-8-51, S/N 45410 only; *T.C. 4A25* | ST00558AT | Increase in aircraft operating weights (Maximum takeoff weight - 315,000 lbs., maximum landing weight - 217,000 lbs., maximum zero fuel weight - 203,000 lbs.) Issued 8/26/94. | CE-A | Aircraft Modification Design Svcs 8960 Ridgemont Drive Atlanta, GA 30350 |

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| DC-8-51, S/N 45935 only; *T.C. 4A25* | ST00617AT | Increase in aircraft operating weights (maximum takeoff weight - 315,000 lbs., maximum landing weight - 217,000 lbs., maximum zero fuel weight - 203,000 lbs. Issued 12/14/94. | CE-A | Aircraft Mod Design Svcs 8960 Ridgemond Drive Atlanta, GA 30350 |
| DC-8-51, -52, -53, -8F-54, -55, -8-55, -61, -61F; T.C. 4A25 | SA2106SO | Installation of a hush kit. Amended 11/9/87. | CE-C | Quiet Nacelle Corporation 8000 N.W. 56th Street Miami, FL 33166 |
| DC-8-51, -52, -53, 8F-54, 8F-55, -55, -61; T.C. 4A25 | SA2411SO | Installation of hush kit. Amended 3/23/90. | CE-A | Quiet Nacelle Corporation 8000 N.W. 56th Street Miami, FL 33166 |
| DC-8-53; *T.C. 4A25* | SA3613WE | Modifications to permit increase in maximum allowable zero fuel weight. Issued 3/27/78/ | WE | G.S. Rasmussen P.O. Box 2052 Glendale, CA 91209 |
| DC-8-53; *T.C. 4A25* | SA3806WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 12/26/78. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-53; *T.C. 4A25* | SA3908WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 4/20/79. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-53; *T.C. 4A25* | SA3909WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 4/20/79. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8-53; *T.C. 4A25* | SA3912WE | Modifications to permit an increase in maximum allowable zero fuel weight. Issued 4/23/79. | WE | G.S. Rasmussen P.O. Box 10519 Glendale, CA 91209 |
| DC-8F-54, S/N 45637 only; *T.C. 4A25* | ST00924AT | Increase in aircraft operating weights (maximum landing weight - 240,000 lbs., maximum zero fuel weight - 224,000 lbs.) Issued 12/4/95. | CE-A | Aircraft Modification Design Services, Inc. 8960 Ridgemont Drive Atlanta GA 30350 |
| DC-8F-54 (S/N's 45802, 45886, 46012 only); *T.C. 4A25* | ST00850AT | Increase in aircraft operating weights as substantiated by the design data. Amended 9/17/96. | CE-A | Aircraft Modification Design Services, Inc. 8960 Ridgemont Drive Atlanta GA 30350 |
| DC-8-61; *T.C. 4A25* | SA4091WE | Deletion of a pair of excess Type 1 exits at station 1124. Issued 1/22/80. | WE | United Airlines, Inc. San Francisco Int'l Arpt San Francisco, CA 94128 |

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| DC-8-61; *T.C. 4A25* | SA5510NM | Modification to permit an increased maximum zero fuel weight (MZFW), and maximum landing weight (MLW). Amended 11/15/96. | NM-L | Structural Integrity Engr 9560 Topanga Canyon Chatsworth CA 91311 |
| DC-8-61; *T.C. 4A25* | ST00266AT | Installation of Pratt and Whitney JT3D-3B engines with long duct nacelles and cutback pylons. Reissued 8/8/94. | CE-A | Airborne Express Inc. 145 Hunter Drive Wilmington, OH 45177 |
| DC-8-61, DC-8-62, -63, -71, -73; *T.C. 4A25* | SA1802SO | Installation of a cargo door, cargo restraint bulkhead, heavy duty flooring, etc., and provisions for 2 additional crew members. Amended 10/15/90. | CE-A | Rosenbalm Avn Inc. P.O. Box 10136 Macon, GA 31297 |
| DC-8-61, -62, -62F, -63, -63F; *T.C. 4A25* | SA4892NM | Modification of the aircraft by installation of noise reduction nacelles. Amended 1/6/95. | NM-L | Burbank Aeronautical Corp. 3000 North Clybourn Ave Hangar 34 Burbank, CA 91505 |
| DC-8-61F, -62F, -63F, -71F, -72F, -73F; *T.C. 4A25* | SA1606SO | Manufacture and installation of cabin/emergency exit window plugs. Issued 5/2/84. | CE-A | Delta Air Lines, Inc. Atlanta Hartsfield Int'l Arpt Atlanta, GA 30320 |
| DC-8-62 (S/N 45925 only); *T.C. 4A25* | ST01363AT | Increase in aircraft operating weights (max landing weight - 250,000 lbs., max takeoff weight - 342,000 lbs.) Amended 11/28/97. | CE-A | Aircraft Modification Design Services, Inc. 8960 Ridgemont Drive Atlanta GA 30350 |
| DC-8-62; *T.C. 4A25* | SA2819WE-D | Installation of Atlantic Aviation wide body kit. Issued 11/8/74. | WE | United Air Lines, Inc. San Francisco Int'l Arpt San Francisco, CA 94128 |
| DC-8-62, -62F, -63, -63F; *T.C. 4A25* | SA1775GL | Incorporate maximum permissible quick turn-around landing weight (flaps 35…) Issued 7/20/92. | CE-C | ABX Air, Inc. 145 Hunter Drive Wilmington, OH 45177 |
| DC-8-63; *T.C. 4A25* | SA1832SO | Installation of a cargo door and cargo interior. Reissued 5/8/95. | CE-A | ATAZ, Inc. P O Box 521477 Miami FL 33152 |
| DC-8-63; *T.C. 4A25* | SA4844NM | Modification in accordance with FAA-approved data to permit an increase in maximum landing weight above 2,000 ft. Issued 3/1/90. | NM | Leth and Associates 85 222nd Place SE Redmond, WA 98052 |
| DC-8-71 (S/N 46099 only); *T.C. 4A25* | ST00794AT | Increase in aircraft operating weights (max takeoff weight - 328,000 lbs., max landing weight - 258,000 lbs., max zero fuel weiht - 245,000 lbs.) Amended 4/24/97. | CE-A | Aircraft Modification Design Services, Inc. 8960 Ridgemont Drive Atlanta GA 30350 |
| DC-8-73, 73F; *T.C. 4A25* | SA6058NM | Modification to permit increase in maximum allowable zero fuel weight .Amended 9/2/94. | NM-L | Altair Holdings Limited 111 N. First Street, Suite 301 Burbank, CA 91502 |

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| DC-9 Series; *T.C. A6WE* | SA4565SW | Installation of sunvisor assembly windshield and inner pane accoustic cabin window. Issued 12/14/81. | SW | Madeira Air Supply, Inc. 3330 Ribelin Way Garland, TX 75042 |
| DC-9-11, -12, -13, -14, -15, -31, -32, -41; *T.C. A6WE* | SA1198SO | Conversion of aircraft from passenger to all cargo configuration. Amended 1/24/92. | CE-C | ABX Air, Inc. 145 Hunter Drive Wilmington, OH 45177 |
| DC-9-11, -12, -13, -14, -15, -15F; *T.C. A6WE* | SA1563GL | Installation of a Stage 3 Hushkit on McDonnell Douglas DC-9-10 series when powered by Pratt & Whitney JT8D-7 series engines. Issued 2/19/91. | CE-C | ABS Partnership P.O. Box 532 Wilmington, OH 45177 |
| DC-9-31, -32, -32F, -33F; *T.C. A6WE* | SA1613GL | Installation of Stage 3 hushkit when aircraft powered by (1) P&W JT8D7 series engines, (2) P&W JT8D-9 series engines. Amended 9/24/92. | CE-C | ABS Partnership 1111 Airport Road Wilmington, OH 45177 |
| DC-9-31, -32, -32F, -33F; *T.C. A6WE* | SA1785GL | Installation of a Stage 3 hushkit on aircraft when powered by (1) P&W JT8D-9 Series engines, (2) P&W JT8D-7 Series engines. Issued 8/25/92. | CE-C | ABS Partnership 145 Hunter Drive Wilmington, OH 45177 |
| DC-9-31, -32, -32F, -33F, -34, -34F, -41; *T.C. A6WE* | ST165CH | Installation of a Stage 3 hushkit when powered by Power & Whitney JT8D-7, -9, or -11 series engines. Issued 1/26/94. | CE-C | ABS Partnership 1111 Airport Rd Wilmington, OH 45177 |
| DC-9-32; *T.C. A6WE* | SA2542SO | Installation of a cargo door. Reissued 9/22/94. | CE-A | Pemco Aeroplex, Inc. P.O. Box 2287 Birmingham, AL 35201 |
| DC-10-10; *T.C. A22WE* | ST00312AT | Modification to allow passenger to freighter conversion. Issued 9/17/93. | CE-A | Federal Express Corp P.O. Box 727 Memphis, TN 38194 |
| DC-10-40, -10-40F; *T.C. A22WE* | SA3139WE | Installation of wing and tail engine pods. Reissued 2/28/95. | NM-L | Rohr, Inc. 850 Lagoon Drive Chula Vista, CA 91910 |

## Appendix F NDI DATABASE

On April 22nd, 1998, the Airworthiness Assurance Working Group (AAWG) generated an action item from the AAWG industry survey on technology readiness for detection of Widespread Fatigue Damage (WFD). Lockheed Martin, Airbus Industrie, Boeing, and the FAA tech Center had just given presentations on crack detectability, based on WFD occurring in four hypothetical structure configurations. The action item requested that the four industry participants coordinate their estimates into a single set of numbers for use by the committee.

The action item has been completed. Reducing NDT data into curves or numerical estimates is a risky activity. Over-simplifications of this sort can result in poor engineering decisions if used without cognizance of the many factors, which influence NDT inspections. However, the participants recognize the need for a basis on which to proceed with the committee's work.

Our response is contained in the data sheets that form a part of this Excel 4.0 file. It represents, in almost all cases, detectability under controlled (laboratory) conditions. Human factors, inspection surface conditions, operator experience level, and other variables have not been considered.
The data also represents use of the optimum NDT method. Many operators will not be using state-of-the-art equipment.

The "database" data sheet contains the individual responses from the participants. The shaded cells in the spreadsheet are those which were used to represent the industry. In most cases these are the largest of the crack sizes provided.

Where possible, 90/95 probability figures were used. However, these can also be subject to misinterpretation as described in the "FAA Tech Center Comment" worksheet of this file.

Assumptions and legends used in providing the estimates, other than those listed here, are shown on the data sheets themselves. The sheets should be printed out before review. Fax copies will be sent where necessary.

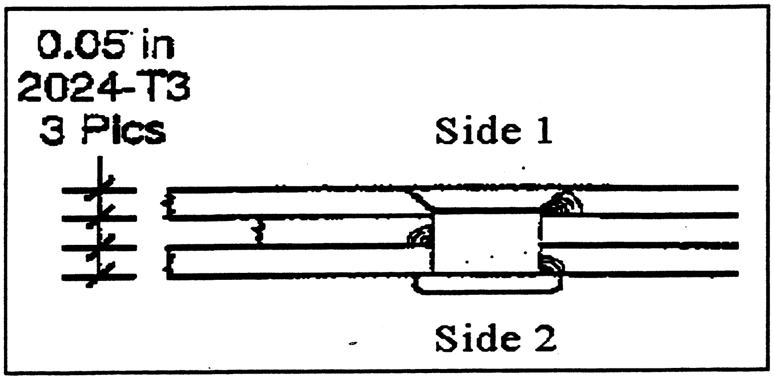
The estimates were provided by:

Daniel Bical (Airbus Industrie)
Don Hagemaier & Jeff Kollgaard (Boeing Commercial Airplane Group)
Don Pettit (Lockheed Martin Aerospace Systems)
Chris Smith & Floyd Spencer (FAA Technical Center)

# Widespread Fatigue Damage Detectability – Database

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 1: Aluminum NAS1097-AD5 flush rivet**




**Side 1:**

| | Boeing Inches | Boeing mm | Airbus Industrie Inches | Airbus Industrie mm | Lockheed Martin Inches | Lockheed Martin mm | FAA Tech Center Inches | FAA Tech Center mm |
|---|---|---|---|---|---|---|---|---|
| CRACK 1: | [illegible] | [illegible] | 0.08 | 2.0 | 0.05 | 1.3 | 0.05 | 1.3 |
| | [illegible] | [illegible] | | | *0.035* | *0.9* | ***0.032*** | *0.8* |
| CRACK 2: | 0.2 | 5.1 | 0.24 | 6.0 | [illegible] | [illegible] | | |
| | *0.1* | *2.5* | | | [illegible] | [illegible] | | |
| CRACK 3: | 0.3 | 7.6 | [illegible] | [illegible] | 0.3 | 7.6 | 0.24 | 6.1 |
| | *0.15* | *3.8* | | | [illegible] | [illegible] | *0.12* | *3.0* |

**Side 2:** Dimension shadowed by upset rivet assumed to be 0.020" (0.5 mm).
Rivet upset assumed to be irregular.

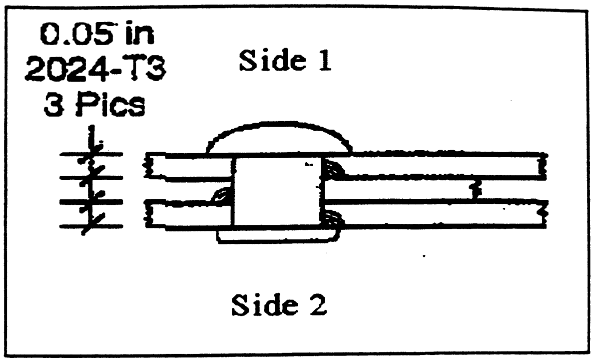
| | Boeing Inches | Boeing mm | Airbus Industrie Inches | Airbus Industrie mm | Lockheed Martin Inches | Lockheed Martin mm | FAA Tech Center Inches | FAA Tech Center mm |
|---|---|---|---|---|---|---|---|---|
| CRACK 1: | 0.083 | 2.1 | [illegible] | 2.5 | [illegible] | 2.5 | | |
| | *0.08* | *2.0* | | | [illegible] | [illegible] | | |
| CRACK 2: | 0.2 | 5.1 | 0.24 | 6.0 | [illegible] | [illegible] | | |
| | *0.125* | *3.2* | | | [illegible] | [illegible] | | |
| CRACK 3: | 0.3 | 7.6 | [illegible] | [illegible] | 0.3 | 7.6 | | |
| | [illegible] | [illegible] | | | [illegible] | [illegible] | | |

Key: current capabilities in plain text, *five year projections in italics*, **90/95 crack lengths in bold**

# Widespread Fatigue Damage Detectability – Database

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 2: Aluminum MS20470 protruding head rivet**




**Side 1:** 0.078" (2.0 mm) = dimension shadowed by MS20470 protruding head

| | Boeing | | Airbus Industrie | | Lockheed Martin | | FAA Tech Center | |
|---|---|---|---|---|---|---|---|---|
| | Inches | mm | Inches | mm | Inches | mm | Inches | mm |
| CRACK 1: | 0.118 | 3.0 | [illegible] | [illegible] | 0.1 | 2.5 | 0.11 | 2.8 |
| | *0.088* | *2.2* | | | [illegible] | [illegible] | | |
| CRACK 2: | 0.2 | 5.1 | 0.24 | 6.0 | [illegible] | [illegible] | | |
| | *0.178* | *4.5* | | | [illegible] | [illegible] | | |
| CRACK 3: | 0.3 | 7.6 | 0.31 | 8.0 | [illegible] | [illegible] | | |
| | *0.228* | *5.8* | | | [illegible] | [illegible] | | |

**Side 2:** Dimension shadowed by upset rivet assumed to be 0.078" (2.0 mm).
Rivet upset assumed to be irregular.

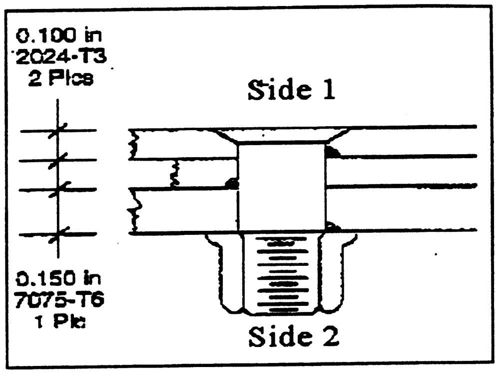
| | Boeing | | Airbus Industrie | | Lockheed Martin | | FAA Tech Center | |
|---|---|---|---|---|---|---|---|---|
| | Inches | mm | Inches | mm | Inches | mm | Inches | mm |
| CRACK 1: | [illegible] | [illegible] | 0.1 | 2.5 | 0.1 | 2.5 | | |
| | [illegible] | [illegible] | | | *0.09* | *2.3* | | |
| CRACK 2: | 0.2 | 5.1 | 0.24 | 6.0 | [illegible] | [illegible] | | |
| | *0.188* | *4.8* | | | [illegible] | [illegible] | | |
| CRACK 3: | 0.3 | 7.6 | [illegible] | [illegible] | 0.3 | 7.6 | | |
| | *0.238* | *6.0* | | | [illegible] | [illegible] | | |

Key: current capabilities in plain text, *five year projections in italics*, **90/95 crack lengths in bold**

## Widespread Fatigue Damage Detectability – Database

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 3: Titanium HLT-335 flush 0.250" (6.3 mm) diameter fastener**




**Side 1:**

| | Boeing | | Airbus Industrie | | Lockheed Martin | | FAA Tech Center | |
|---|---|---|---|---|---|---|---|---|
| | Inches | mm | Inches | mm | Inches | mm | Inches | mm |
| CRACK 1: | 0.1 | 2.5 | 0.1 | 2.5 | [redacted] | [redacted] | | |
| | *0.1* | *2.5* | | | [redacted] | [redacted] | | |
| CRACK 2: | 0.3 | 7.6 | 0.31 | 8.0 | [redacted] | [redacted] | | |
| | *0.15* | *3.8* | | | [redacted] | [redacted] | | |
| CRACK 3: | 0.55 | 14.0 | [redacted] | [redacted] | 0.6 | 15.2 | | |
| | *0.25* | *6.4* | | | [redacted] | [redacted] | ***0.1*** | ***2.5*** |

**Side 2:** Dimension shadowed by fastener collar assumed to be 0.125" (3.2 mm).
No sealant cap present.

| | Boeing | | Airbus Industrie | | Lockheed Martin | | FAA Tech Center | |
|---|---|---|---|---|---|---|---|---|
| | Inches | mm | Inches | mm | Inches | mm | Inches | mm |
| CRACK 1: | 0.125 | 3.2 | 0.12 | 3.0 | [redacted] | [redacted] | | |
| | *0.1* | *2.5* | | | [redacted] | [redacted] | | |
| CRACK 2: | [redacted] | [redacted] | 0.39 | 10.0 | 0.3 | 7.6 | | |
| | [redacted] | [redacted] | | | *0.25* | *6.4* | | |
| CRACK 3: | [redacted] | [redacted] | | | 0.6 | 15.2 | | |
| | [redacted] | [redacted] | | | *0.5* | *12.7* | | |

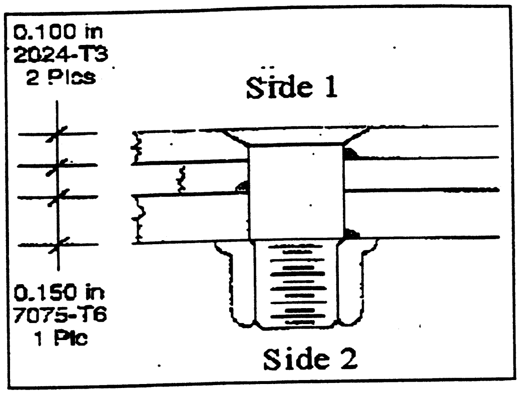
NOTE: Inspection for crack 3 from side 2 is a very unlikely inspection scenario.

Key: current capabilities in plain text, *five year projections in italics*, **90/95 crack lengths in bold**

# Widespread Fatigue Damage Detectability – Database

(All cracks measured from shank of fastener, cracks numbered in ascending order from inspection side)

**Case 4: Steel HLT-41 flush 0.250" (6.3 mm) diameter fastener**




**Side 1:**

| | Boeing Inches | Boeing mm | Airbus Industrie Inches | Airbus Industrie mm | Lockheed Martin Inches | Lockheed Martin mm | FAA Tech Center Inches | FAA Tech Center mm |
|---|---|---|---|---|---|---|---|---|
| CRACK 1: | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | | |
| | [redacted] | [redacted] | | | *0.09* | *2.3* | | |
| CRACK 2: | [redacted] | [redacted] | 0.31 | 8.0 | 0.25 | 6.4 | | |
| | *0.15* | *3.8* | | | [redacted] | [redacted] | | |
| CRACK 3: | [redacted] | [redacted] | 0.79 | 20.0 | 0.4 | 10.2 | | |
| | *0.25* | *6.4* | | | [redacted] | [redacted] | ***0.1*** | ***2.5*** |

**Side 2:** Dimension shadowed by fastener collar assumed to be 0.125" (3.2 mm).
No sealant cap present.

| | Boeing Inches | Boeing mm | Airbus Industrie Inches | Airbus Industrie mm | Lockheed Martin Inches | Lockheed Martin mm | FAA Tech Center Inches | FAA Tech Center mm |
|---|---|---|---|---|---|---|---|---|
| CRACK 1: | [redacted] | [redacted] | 0.12 | 3.0 | 0.1 | 2.5 | | |
| | [redacted] | [redacted] | | | *0.09* | *2.3* | | |
| CRACK 2: | [redacted] | [redacted] | 0.39 | 10.0 | 0.25 | 6.4 | | |
| | [redacted] | [redacted] | | | *0.2* | *5.1* | | |
| CRACK 3: | [redacted] | [redacted] | | | 0.45 | 11.4 | | |
| | [redacted] | [redacted] | | | *0.35* | *8.9* | | |

NOTE: Inspection for crack 3 from side 2 is a very unlikely inspection scenario.
Key: current capabilities in plain text, *five year projections in italics*, **90/95 crack lengths in bold**

# Appendix G PROPOSED ARAC TASKING STATEMENT FOR FOLLOW-ON TASKING

## HARMONIZATION TERMS OF REFERENCE

<u>TITLE OF INITIATIVE</u>: FAR/JAR 25 AGING AIRCRAFT

**AFFECTED FAR SECTION NUMBER (S):** New FAR Sections(s) to be proposed.
**AFFECTED JAR PARAGRAPH NUMBER (S):** New JAR Sections(s) to be proposed.
**NPA/NPRM NUMBER:**
**ADVISORY MATERIAL NUMBER:**

**<u>BACKGROUND:</u>**

The FAA and JAA have been working together on the structural issues of aging aircraft to 1) assess the progress that has been made on the original eleven model aging aircraft, 2) identify any additional activities that are necessary to ensure the continued airworthiness of those aircraft and 3) apply the lessons learned on the original eleven model aging aircraft to other airplanes used in air transportation.

Under a previous ARAC tasking, the Airworthiness Assurance Working Group (AAWG) developed a new appendix to Advisory Circular 91-56. The appendix provides guidance on the development of a Widespread Fatigue Damage (WFD) prediction and verification technique to preclude operation of transport airplanes in the presence of WFD. Although the type certificate holders of the original eleven models agreed to develop a comprehensive evaluation program for potential WFD, commercial changes have affected some of the type certificate holders since that commitment was made and Advisory Circular 91-56 was revised. At this time the program is voluntary. The FAA was concerned that certain model specific programs may not be developed prior to the fleet leaders reaching their design service goal therefore the ARAC was tasked to provide guidance on how to proceed if the voluntary program does not protect the fleet.

ARAC was tasked to review the capability of analytical methods and their validation; related research work; relevant full-scale and component fatigue test data; and tear down inspection reports, including fractographic analysis, relative to the detection of widespread fatigue damage.

ARAC was also tasked to propose time standards for the initiation and completion of model specific programs (relative to the airplanes design service goal) to predict, verify and rectify widespread fatigue damage and to recommend action that the Authorities should take if a program, for certain model airplanes, is not initiated and completed prior to those time standards.

ARAC is in the final stages of completing this task and has issued an early recommendation that they be tasked to develop regulations to ensure that no large transport category airplane (>75,000 lbs. Gross Takeoff Weight) operates with widespread fatigue damage. This recommendation is based on evidence, gathered by ARAC from relevant tests and examples from service, that multiple site and multiple element damage exists in several different airplane types in the fleet. Such damage is a potential precursor to widespread fatigue damage.

Due to the extent of multiple site damage and multiple element damage that has been found in the fleet prompt action is necessary. This tasking warrants expeditious action to prevent a safety problem and to preclude unplanned grounding of a significant portion of the fleet of large transport airplanes due to a finding of widespread fatigue damage. ARAC has determined that there is a need to mandate that a widespread fatigue damage program is in place by Dec. 31, 2002.

**SPECIFIC TASK:**

ARAC is tasked to develop regulations (14 CFR part 25 and part 121 et. al) to ensure that one year after the effective date of the rule (e.g. Dec. 31, 2002), no large transport category airplane (> 75,000 lbs. Gross Take off Weight) may be operated beyond the flight cycle limits to be specified in the regulation unless an Aging Aircraft Program has been incorporated into the operators maintenance program.

The regulations and advisory material shall establish the content of the Aging Aircraft Program. This program shall cover the necessary special inspections and modification actions for the prevention of Widespread Fatigue Damage (WFD), Structural Modifications, Supplemental Structural Inspections Programs (SSIP)/Airworthiness Limitations Instructions (ALI), Corrosion Prevention and Control Programs (CPCP) and Structural Repairs. The regulations will also require the establishment of a limit of the validity of the Aging Aircraft Program where additional reviews are necessary for continued operation.

This Task shall be completed within 9 months of tasking.

Milestones:

A. Recommend a plan for completion of the task, including rationale, for FAA/JAA approval within three months of publication of this notice.
B. Give a status report on each task at each ARAC issues meeting.

**CONTACTS:**

**REMARKS**:

**BENEFITS OF HARMONIZATION:** Harmonization would improve safety by assuring a common approach to the aging aircraft program.

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